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THE JULY SCIENTIFIC MONTHLY

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(Continued on page ii)

THE SCIENTIFIC MONTHLY

JULY, 1929

FISHING WITH THE CORMORANT IN JAPAN

By Dr. E. W. GUDGER

AMERICAN MUSEUM OF NATURAL HISTORY

Introduction

I HAVE previously published[1] a historical paper on this method of fishing in the former Celestial Empire, and the present article is intended to bring together with suitable illustrations the accounts of the like use of this bird in Japan—the Land of the Rising Sun.

This method of taking fishes in China undoubtedly goes back into remote antiquity, but Chinese records are unfortunately lacking. Still one authority was found to state that it was seemingly established under the Sung dynasty, somewhere between A. D. 960 and 1288. However, as will be shown later herein, it seems not improbable that cormorant fishing was carried on at a much earlier date. The first European who saw it was Friar Odoric, of Pordenone, and the first printed account is in his book "Odorichus de Rebus Incognitis," Pesaro, 1513. It was, however, a well-established custom in China at the time of his visit (1325–1328).

For Japan, in contrast, definite notices of fishing with the cormorant are found in two early chronicles. In A. D. 682 the Emperor Tem-mu had the existing chronicles examined critically, digested and set out in definite form by a scribe named Hiyeda no Are. Tem-mu died before this was finished, but twenty-five years later the Empress Gemmio had Are collaborate with one Yasumaro, a court noble, in the final production of the "Kojiki" (Records of Ancient Things) in A. D. 712. This remained in manuscript until first published in Japanese in 1644, since which time numerous editions in the native language have appeared.

The "Kojiki" probably had its source in large part in the similarly named "Kiujiki" or "Kujiki" (Chronicles of Old Matters), which was compiled in A. D. 620 but was almost completely destroyed by fire about or shortly after 645; or at any rate in the remnant of the above saved from the flames and known as "Kokuki" or national annals. The "Kojiki" was translated into English by Basil Hall Chamberlain, published in 1882 and republished in 1920. From this latter publication the citations, presently to be given, are taken.[2]

The other work indicated above is the "Nihongi" (Chronicles of Japan from the Earliest Times). This was completed and submitted in A. D. 720 to the Empress Gemmio by Prince Toneri and the same Yasumaro referred to above. The

[1] E. W. Gudger, "Fishing with the Cormorant: I. In China," *American Naturalist*, 60: 5–41. 16 figures. 1926.

[2] Basil Hall Chamberlain, "Ko-ji-ki: Records of Ancient Matters" (trans.), *Transactions Asiatic Society of Japan*. Tokyo. Supp. to vol. 10, pp. 167 and 176. 1920. This is a reprint of the original article of 1882.

—Courtesy of Gifu Municipal Office

FIG. 1. A FLOTILLA OF SIGHTSEEING BARGES

DRAWN UP AT THE LANDING PLACE ON THE NAGARA RIVER, GIFU. THEY ARE READY TO CONVEY TOURISTS TO THE CORMORANT-FISHING GROUNDS.

"Kojiki" seems to be almost wholly Japanese in origin, but the "Nihongi," which is based largely on the "Kojiki," on other chronicles and various scattered records, is said to show many traces of the strong Chinese influences then prevalent at the court of the Empress Gemmio. It is, moreover, very much larger than the "Kojiki." The "Nihongi" has passed through many editions. The one quoted herein is the English version by W. G. Aston, published in 1896.[3]

With these brief historical remarks, quotation will now be made of the earliest known accounts of fishing with the cormorant in Japan. There are two citations in the "Kojiki," both found in the accounts of a journey eastward through his domain of the Emperor Jim-mu. The first is found in volume 2, section 46, and reads as follows:

> So on making his progress . . . he reached the lower course of the Yeshinu [Yoshino] River, where there was a person catching fish in a weir. Then the august child of the Heavenly Deity [the Emperor] asked, saying "Who art thou?" He [the fisherman] replied, saying: "I am an Earthly Deity and am called by the name of Nihe-motsu no Ko." This is the ancestor of the cormorant keepers of Aha.

The second reference, and a very definite one, is found in book 2, section 49. Here, when the Emperor Jim-mu had fought and had smitten both Shiki the Elder and Shiki the Younger, he and

[3] W. G. Aston, "Nihongi: Chronicles of Japan from the Earliest Times to A. D. 697" (trans.), *Transactions and Proceedings Japan Society*, London, vol. 1 (Suppl. 1), pp. 119, 126, 341. The reader interested in the history of these old chronicles will find full discussions in the introductions to the works of Aston (1896) and Chamberlain (1920).

his army were faint for want of food and he sang this song:

As we fight placing our shields in a row, going and watching from between the trees on Mount Inasa, oh! we are famished. Ye keepers of cormorants, the birds of the island, come now to our rescue.

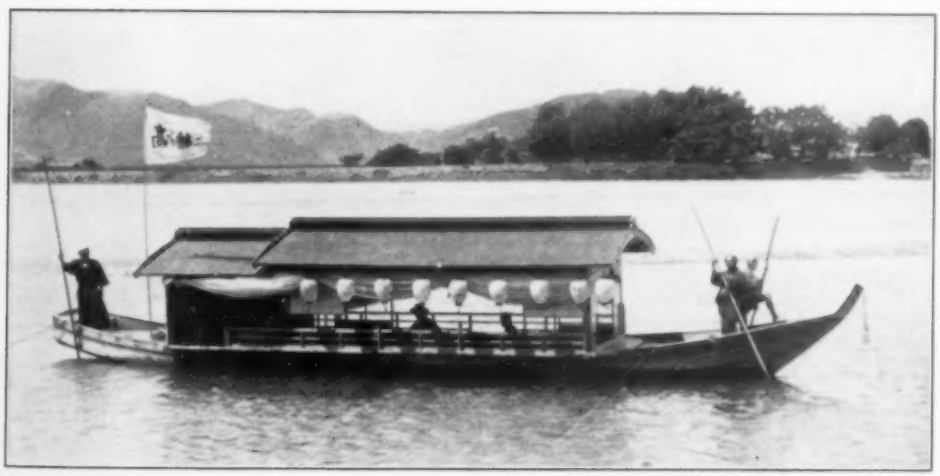
Chamberlain's note on this is: "This song is a request for provisions made by the emperor to some fishermen who were working the cormorants along the mountain streams." Here, then, we have a plain indication of the use of the cormorant as a fisher long before A. D. 712.

In the "Nihongi" (A. D. 720), in book 3, section 15, is found in almost identical language the incident quoted above from the "Kojiki." But the explanatory statement here reads of Nihemotsu that, "He it is who was the first ancestor of the U-Kahi of Aha"—the word U-Kahi meaning cormorant keepers. Again on page 126 (book 3, section 24), the song of the emperor is set in (modern) poetic form thus:

As we fight
Going forth and watching
From between the trees
Of Mount Inasa,
We are famished.
Ye keepers of cormorants
(Birds of the island)
Come now to our aid.

And finally (book 14, section 12) where the scene is located on the River Ihoki, there is found the statement that the Emperor Oho-hatsuse Wakatake persuaded one Takehiko to go with him to the river, and "There, pretending to make cormorants dive into the water to catch fish, he took him unawares and slew him."

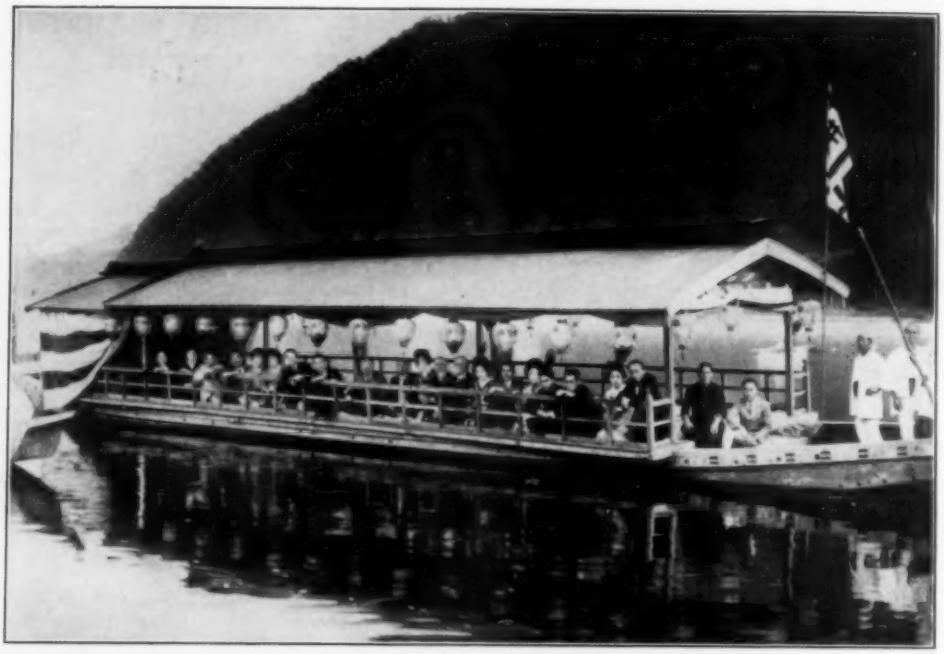
These citations show that fishing with the cormorant was practiced in Japan, perhaps in prehistoric days, certainly long before A. D. 612. Whether this practice arose spontaneously in Japan or whether it was brought from China can not be stated definitely. However, since most students of the Orient think that the early culture of Japan had its source in China, it seems not improbable that this method of fishing was imported from China at a very early date. How this importation was made is not certainly known, but one can infer that, in



—*Photograph by Dr. H. M. Smith*

FIG. 2. A SMALL BARGE

FROM WHICH TO VIEW CORMORANT FISHING AT GIFU ON THE NAGARA RIVER.



—Photograph by courtesy of Gifu Municipal Office

FIG. 3. A LARGE BARGE

USED TO CONVEY THE SPECTATORS FROM GIFU TO AND ABOUT THE CORMORANT-FISHING GROUNDS. NOTE THE KITCHEN IN THE REAR.

the early diplomatic intercourse between China and Japan, cormorants may have been carried from the former to the latter country.

That there was such early intercourse is made clear by Hervey Saint-Denys (1871) in his critical memoir on the "Ouen Hein Tong Kao" (Profound Researches into Ancient Monuments) of Ma-Touan-Lin.[4] This great Chinese scholar and critic composed his encyclopedic work in the thirteenth century A. D. His chronicle covers the history of China from about 2400 B. C. to about A. D. 1300. In it he records periodical Chinese embassies to Japan from about A. D. 200 on. Hervey Saint-Denys works out the dates of certain early embassies as of A. D. 246, 416 and 425—from which latter time on they were frequent. More to our matter the French critic quotes Ma-Touan-Lin that:

> The inhabitants [of Japan] dive into the water to catch fish. They also have cormorants with the neck of each surrounded by a little ring to prevent swallowing, and they train them to catch fish. In this way they take in a day several hundred fish.

If now the commonly held belief be accepted that Chinese culture and civilization (including the use of the cormorant in fishing) antedated that of Japan, then, since we have dates for the sending of Chinese embassies to Japan, we need not find it difficult to believe that the Japanese learned this method

[4] Hervey Saint-Denys (Marquis de), "Ma-Touan-Lin. Ethnographie des peuples étrangers à la Chine, Ouvrage composé au XIIIe siècle de notre ére par Ma-Touan-Lin." Genève, "Orientaux," p. 79 (trans.), 1876; "Mémoire sur l'histoire ancienne du Japon, d'après le Ouen Hien Tong Kao de Ma-Touan-Lin," *Journal Asiatique*, Paris, 6. series, tome 18, pp. 386 and 403. 1871.

of taking fish from the Chinese, and indeed possibly got their first birds from these embassies.

Both Aston and Hall affirm that fishing with the cormorant in Japan was a common thing during the Middle Ages and up to the Renaissance, but other records filling in the gap between the distant past and the comparatively recent years are few. So far as I have searched, unlike similar works for China, none of the early European voyagers to Japan, not even Kaempfer, figures or even refers to cormorant fishing in Japan. The explanation for this is to be found in the fact that Japan is largely mountainous with little plain or flat country (as in China) near the ports. Cormorant fishing in Japan seems always to have been practiced only in a few upland or mountainous sections to which the early voyagers probably never penetrated.

In fact, the only early accounts additional to those given above have been found in articles on cormorant fishing in the Land of the Rising Sun by two Japanese scholars, Ikenoya (1917) and Kuroda (1926). The latter was commissioned by the imperial government to investigate and write up this fishing in Japan, and from the data thus officially obtained the article referred to (1926) was prepared. The former alleges that cormorant fishing was carried on during the Heian era in the province of Mino—no river specified, though it is probable that this was the Nagara as noted below. All the other citations of this fishing locate it more narrowly and will be set out by regions.

While cormorant fishing in China is purely a commercial proposition, carried on throughout the entire length and breadth of the great plain of China, in Japan it is practiced only in certain restricted localities and there partly as a business but largely as a matter of sport intended to attract tourists. In China, as my previous studies have shown, this fishing is carried on only in the daytime. But in Japan, in keeping with its sporting character, it is carried on mainly at night, in one locality in both night and day, and occasionally (as a commercial proposition entirely) in some sections in daytime only. Furthermore in Japan the birds seem to be

—Picture by courtesy of Gifu Municipal Office

FIG. 4. THE FISHING BOATS DRIFT SLOWLY DOWN THE STREAM
THEIR LIGHTED CRESSETS GIVING REMBRANDT-LIKE EFFECTS IN THE INKY DARKNESS.

—By courtesy of Gifu Municipal Office

FIG. 5. DISTANT VIEW OF THE CORMORANT FISHING
ON THE NAGARA RIVER, THE BARGE WITH SPECTATORS IN THE RIGHT FOREGROUND.

used for taking practically only one fish, the *ayu* or sweet-fish, *Plecoglossus altivelis*, a salmonid reaching about a foot in length and found only in the clear upland and mountain streams of central Japan. Since the accounts of this fishing specify the use of the birds on certain streams only, my data will be presented under these locality headings, beginning with that one where it has been longest carried on and is to-day most prosecuted.

FISHING WITH CORMORANTS ON THE NAGARA RIVER FROM A. D. 900 TO 1877

It seems well to segregate the old accounts of fishing on this river from the recent ones. The former are very fragmentary, the latter very detailed. The former are interesting historically, while the latter are delightful accounts of a most attractive fishing method.

The earliest record I find (on the authority of Kuroda) is that during the Engi era (A. D. 901–922) there were seven cormorant fishers' cottages on the Nagara. From their catches dried *ayu* were sent to the imperial court by Toshihito Fujiwara, governor of Mino province. During the Jimpei era (1151–1153) it is recorded that these cottages had increased to twenty-one in seven villages. In 1159, the first year of the Heiji era, Yoshitomo Minamoto put up a cormorant fisher's cottage on the lower Nagara River, and received tribute of the fishes caught. Again in 1190 it is on record that a cormorant fisher sent to the same official presents of "sugared sweet-fish and rice," thus establishing the custom. And later Zenkakei Kaneyashi Ichigo was present at a cormorant fishing in the Nagara in the Bummei era (1469–1486), about the time when Columbus was seeking aid for his westward voyage to the Indies.

In 1504 it is said that there was in one of these villages on the Nagara a girl named Ako who was reputed to be very skilful in the handling of cormorants, as is evidenced by her driving twelve at once (note the number twelve which is the normal number for a master cormorant fisher to-day). "This lady of old is regarded as the mother of *ugai* (cormorant fishing)" (Ikenoya). In 1564 (the seventh year of Eiroku), Nobunaga Oda saw the fishing near

Gifu, raised the cormorant fishers to equivalent rank with the falconers, giving each fisher the title *U-jo*, or cormorant tamer, and gave each family a pension in the form of a bag of rice each month and the present of a new boat every four or five years.

For the 1600's we have numerous references. In the opening year of the century (the fifth of the Keicho era), certain troops advanced into the valley of the Nagara and their commander ordered the cormorant tamers to serve as porters for his army. They refused and all their houses were burned. However, three years later, Iyeyasu Tokugawa was presented with the products of the fishery, and in 1615 (first year of the Genna era) he visited Gifu and was greatly pleased with the cormorants at work. On leaving he ordered the *ugai* men to send fish to Yedo twice a month during the season, and this was also required by his successors for many years—there is a record for 1665. The fish were packed in kegs and reached Yedo in two days' time.

In 1707 (fourth year of the Hoyei era) definite family names were conferred on the three chief cormorant tamers. In 1808 (fifth year of Bunka era), the cormorant tamers had been reduced to twelve (a number having left off this fishing), and these received specified allowances of rice and money. In 1867 they were ordered to send a definite tribute of pickled *ayu* to Kyoto, but in 1873 the preferential treatment afforded them was abolished and they were ordered to pay an *ayu*-fishing tax directly to the Gifu prefecture.

In 1878, and again in 1880, the Emperor Meiji visited Gifu and saw the fishing, and in 1888 or 1890 he issued a decree setting aside three imperial fishing places on the Nagara. These were attached to the Grand Veneur's Bureau of the Imperial Household Department. These are: the lower at Furutsu, Nagara-mura; the middle at Tachibana,

—After Pichot, probably from Layrle

FIG. 6. ANOTHER VIEW OF CORMORANT FISHING
IN A WIDE REACH OF THE NAGARA RIVER NEAR GIFU.

—After Mrs. Cochrane, by courtesy of "Asia"

FIG. 7. THE CORMORANT TAMER

HOLDING THE REINS IN HIS LEFT HAND, HE TAKES THE BIRD'S NECK IN HIS RIGHT AND MAKES IT DISGORGE ITS CATCH.

Suhara-mura, and the upper at Ueda, Takeda-mura—all in Gifu prefecture. In 1921, these imperial fishing places were placed under the jurisdiction of the hunting section of the Imperial Household Department.

Here then we have an epitomized sketch of the history of the fishing on the Nagara River as contained in Japanese records and written down by Kuroda (1926). He further states that since the Meiji restoration the witnessing of cormorant fishing on the Nagara has become a fashionable recreation, attended at times by the emperor and his household, by distinguished visitors from abroad, as well as by many native visitors—numbering many thousands each year. This fishing will now be described.

PRESENT-DAY FISHING AT GIFU ON THE NAGARA RIVER AT NIGHT FROM BOATS

Gifu, a city of some 50,000 inhabitants, is situated on the Nagara River in south

central Japan. This river is formed of four tributaries which rise in the slopes of Mt. Dainichigatake, and in the greater part of its lower course is navigable for small boats. It empties into Owari Bay.

The earliest printed account known to me of fishing on the Nagara, and indeed of cormorant fishing in all Japan, excepting the printing in Japanese of the old chronicles noted above, dates back no farther than 1877. In this year Gregory published an article[5] in which he describes this fishing with cormorants in the Nagara. He explains that the cormorants are caught on the island of Susashima in Owari by placing wooden images of them in places which they frequent, and by covering the branches of the nearby trees with birdlime. One cormorant caught, others are attracted and in turn are caught. Then he continues as to their use that:

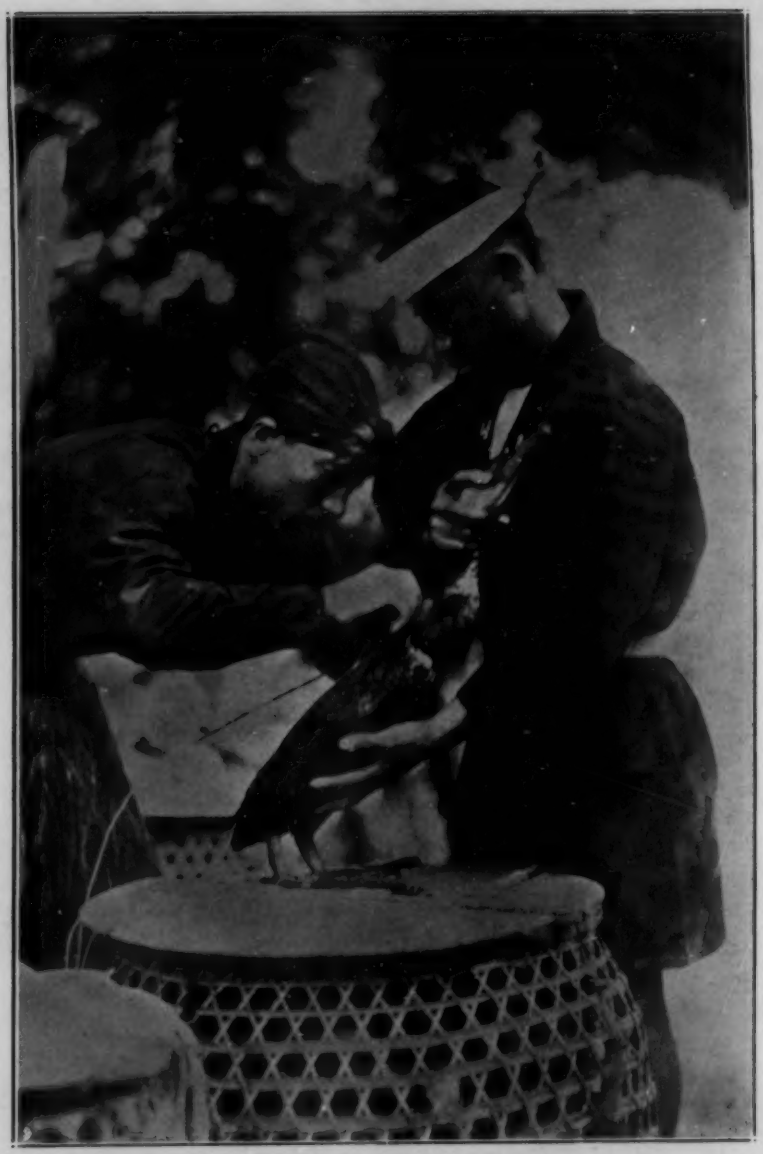
> Near the Nagara River are seven houses, the occupants of which are employed in fishing with cormorants. In each of these houses are kept, on an average, sixteen birds. From the first of the fourth month until the end of the eighth month fishing in the River Nagara is carried on every night. The fishermen go out in long boats which at their bows are furnished with fire baskets or cressets. The fish having been attracted by the light from the fires in these, the birds are sent into the water.

[5] George Elliott Gregory, "Japanese Fisheries," *Transactions Asiatic Society Japan*, Yokohama, 5: 102–113. "Cormorant Fishing," pp. 110–111. 1877.

—*Photograph by Dr. H. M. Smith*

FIG. 8. THE HEAD FISHERMAN AND HIS ASSISTANT

PUTTING THE HARNESS ON ONE OF THE BIRDS. THE BASKETS ARE TWO-CHAMBERED AND HOLD TWO CORMORANTS EACH.



—After Mrs. Cochrane, by courtesy of "Asia"

FIG. 9. HARNESSING THE CORMORANTS AT GIFU

NOTE THE STANDARDIZED METHOD. THIS PICTURE WAS TAKEN MORE THAN TWENTY YEARS LATER THAN DR. SMITH'S.

The cormorant, after having caught a fish, is drawn into the boat, and, the fish being taken from it, it is sent into the water again. Large *ayu* fish weigh as much as three quarters of a pound and the cormorant often swallows five or six fish of this weight. Thus in an hour's time one boat often takes two hundred fish. Very much, however, depends upon the skill of the fisherman, the tying up of the necks and bodies of the birds so that they be neither too tight nor too loose, and upon the care taken in giving the birds the proper quantity of food.

Gregory also describes the method of training the cormorants, the earliest known to me for Japan. He writes that:

From the commencement of the ninth month (October 3) until the commencement of the fourth month (May 7) of the following year the birds are fattened. As above mentioned the houses in which cormorants are kept amount to seven, possessing a total of about one hundred and twelve birds. These are trained in the following manner. All the one hundred and twelve birds are sent off together on the River Nagara; the fishermen encouraging them to fish by uttering cries of *Aika! Aika!* The birds dive and catch and eat fish of all sizes (at this time their necks and bodies are not tied up); after having eaten enough they are driven together by help of the boats, none ever escaping. Each of the owners then picks out his own birds from the flock, recognizing them by their heads, and takes them into his boat. Should it happen that a bird strays, the fisherman recalls it by crying *Ko, ko, ko!* at the same time holding up a fish which he gives to it on its return. The birds are fed but once a day and in the manner just described. Trained birds have a cord tied round their necks to prevent them from swallowing the fish entirely, but they are able to swallow small fish notwithstanding. It is not necessary, if they have been out some time, to give them any other food. In the night after having finished fishing in the river, should any of the birds evidently still be hungry they are fed with fish. After this all the birds are taken to their quarters, when it is necessary, however, to tie a piece of cord (made of straw) round their necks to prevent them from vomiting the fish they have taken for food. Every day at about ten o'clock the birds are placed four together in baskets and conveyed to the river to drink.

In summer to protect the birds from the mosquitoes, which would otherwise trouble them very much, their quarters are surrounded with mosquito nets.

The next account I have found is in the London *Times* for August 21, 1889 (p. 4). This is labeled "From our Tokio correspondent" and is without signature, but Basil Hall Chamberlain (previously referred to) in his book, "Things Japanese,"[6] quotes this account and attributes it to a Major-General Palmer, Royal Engineers. This account is such a very detailed and interesting one and one so evidently written by an eye-witness that it will be liberally quoted. Palmer writes that a dark night should be chosen and that the river should be free from turbidity. On such a night his party embarked on a beautifully decorated, equipped and be-lanterned, roomy barge, having a tiny kitchen for providing the sightseers with fruits, sweetmeats, hot tea and "spitchcocked eels piping hot." Such a fleet of barges,[7] plentifully bedecked with pennants and with Japanese lanterns, is shown in Fig. 1. These are drawn up on the shore of the Nagara River at Gifu and are ready to take tourists up the river at night to witness the cormorant fishing. Such a single barge is portrayed in Figs. 2 and 3. Thus equipped, the attendants poled and towed the barge with the sightseers up the Nagara until finally it was anchored to await the coming of the piscatory craft of the cormorant tamers. We will let Palmer describe the scene in his own words:

Presently the first sign is detected—a spot of hazy, red glow, shining over the trees from a reach two or three miles above us. Hereupon our chief boatman erects his private signal—a mighty paper lantern of a red and white basket pattern. Steadily the glow spreads and deepens, until, as the last intervening point is cleared, we descry its cause—a constellation of shifting, flickering lights, drifting down the dark river towards us. By degrees these develop into balls of fire, seven in number, casting as many long coruscations of light before them, from their reflection on the waters of the stream. Then sounds are heard—sounds of much beating, shouting and splashing. Next appear the forms of boats and the swarthy figures of men thrown up with weird, Rembrandt-like effects against the inky blackness of

[6] Basil Hall Chamberlain, "Things Japanese." Tokyo, 1898. "Cormorant Fishing," pp. 95–98.

[7] For this and many other pictures used herein, I am under obligation to the authorities of the Gifu Municipal and Prefectural Offices, who sent large numbers of pictures together with descriptive literature (largely in Japanese).

—Photograph by courtesy of Gifu Municipal Office

FIG. 10. THE FISHERMEN'S BOAT

DRAWN TO SHORE IN A QUIET COVE WHILE THE BIRDS ARE BEING MADE READY FOR FISHING.

the night; and in the water round about the boats are numbers of cormorants, behaving to all appearance in the maddest fashion. The fires, we now see, are great cages of blazing pine-knots, suspended over the bow of each boat, darting forth flames and sparks, and forever dropping embers, which fall with loud hissing into the stream. Nearer still they come. The men have seen our signal, and are manœuvring so as to surround us; which being done, we find ourselves in the midst of the uproar and excitement of cormorant-fishing *à la Japonaise*.

This night scene is well portrayed in Fig. 4, while Figs. 5 and 6 (evidently taken in the daytime) show how the boats and cormorants come down the river spread out so as thoroughly to cover the water. How the fishing is carried out from the boats is thus described by General Palmer:

There are, to begin with, four men in each of the seven boats, one of whom, at the stern, has no duty but that of managing his craft. In the bow stands the master, distinguished by the peculiar hat of his rank, and handling no fewer than twelve trained birds with the surpassing skill and coolness that have earned for the sportsmen of Gifu their unrivaled preeminence. Amidships is another fisher, of the second grade, who handles four birds only. Between them is the fourth man, called *kako*, from the bamboo striking instrument of that name, with which he makes the clatter necessary for keeping the birds up to their work; he also encourages them by shouts and cries, looks after spare apparatus, etc., and is ready to give aid if required. Each cormorant wears at the base of its neck a metal ring, drawn tight enough to prevent marketable fish from passing below it, but at the same time loose enough—for it is never removed—to admit the smaller prey, which serves as food. Round the body is a cord, having attached to it at the middle of the back a short strip of stiffish whalebone, by which the great awkward bird may be conveniently lowered into the water or lifted out when at work; and to this whalebone is looped a thin rein of spruce fiber, twelve feet long, and so far wanting in pliancy as to minimize the chance of entanglement. When the fishing ground is reached, the master lowers his twelve birds one by one into the stream and gathers their reins into his left hand, manipulating the

latter thereafter with his right as occasion requires. No. 2 does the same with his four birds; the *kako* starts in with his volleys of noise; and forthwith the cormorants set to at their work in the heartiest and jolliest way, diving and ducking with wonderful swiftness as the astonished fish come flocking towards the blaze of light. The master is now the busiest of men. He must handle his twelve strings so deftly that, let the birds dash hither and thither as they will, there shall be no impediment or fouling. He must have his eyes everywhere and his hands following his eyes. Specially must he watch for the moment when any of his flock is gorged—a fact generally made known by the bird itself, which then swims about in a foolish, helpless way, with its head and swollen neck erect. Thereupon the master, shortening in on that bird, lifts it aboard, forces its bill open with his left hand, which still holds the rest of the lines, squeezes out the fish with his right [Fig. 7] and starts the creature off on a fresh foray—all this with such admirable dexterity and quickness that the eleven birds still bustling about have scarce time to get things into a tangle, and in another moment the whole flock is again perfectly in hand.

This account gives the reader an excellent idea of this combined sport and business. Equally clear is Palmer's circumstantial account of the training and behavior of the birds. This gives the details entirely lacking in Gregory's brief statement. He writes that:

As for the cormorants, they are trained when quite young, being caught in winter with bird-lime on the coasts of the neighboring Owari Gulf, at their first emigration southward from the summer haunts of the species on the northern seaboard of Japan. Once trained, they work well up to fifteen, often up to nineteen or twenty years of age; and, though their keep in winter bears hardly on the masters, they are very precious and profitable hunters during the five-months' season and well deserve the great care that is lavished upon them. From four to eight good-sized fish, for example, is the fair result of a single excursion for one bird, which corresponds with an average of about one hundred and fifty fish per cormorant per hour, or four hundred and fifty for the three hours occupied in drifting down the whole course. Every bird in a flock has and knows its number;

—Figure (posed in the daytime) by courtesy of Gifu Municipal Office

FIG. 11. A CORMORANT-FISHING BOAT

MEN AND BIRDS READY TO START OUT. THE U-JO HOLDS THE REINS IN HIS LEFT HAND AND SORTS THEM WITH HIS RIGHT. ONLY EIGHT BIRDS ARE VISIBLE.

—*Photograph by courtesy of the authorities of Inuyama*

FIG. 12. NIGHT FISHING AT INUYAMA

THE CRANE WITH ITS CRESSET HAS BEEN SWUNG ALONGSIDE THE BOAT. THE U-JO IS HANDLING NINE BIRDS. EIGHT ARE SWIMMING ON THE SURFACE AND ONE HAS DIVED IN PURSUIT OF A FISH.

FACE AND ONE HAS DIVED IN PURSUIT OF A FISH.

and one of the funniest things about them is the quick-witted jealousy with which they invariably insist, by all that cormorant language and pantomimic protest can do, on due observance of the recognized rights belonging to their individual numbers. No. 1, or "Ichi," is the *doyen* of the corps, the senior in years as well as rank. His colleagues, according to their age, come after him in numerical order. Ichi is the last to be put into the water and the first to be taken out, the first to be fed, and the last to enter the baskets in which, when work is over, the birds are carried from the boats to their domicile. Ichi, when aboard, has the post of honor at the eyes of the boat. He is a solemn, grizzled, old fellow, with a pompous, *noli me tangere* air that is almost worthy of a Lord Mayor. The rest have places after him, in succession of rank, alternately on either side of the gunwale. If, haply, the lawful order of precedence be at any time violated—if, for instance, No. 5 be put into the water before No. 6, or No. 4 be placed above No. 2—the rumpus that forthwith arises in that family is a sight to see and a sound to hear.

But all this while we have been drifting down, with the boats about us, to the lower end of the course, and are again abreast of Gifu, where the whole squadron is beached. As each cormorant is now taken out of the water, the master can tell by its weight whether it has secured enough supper while engaged in the hunt; failing which, he makes the deficiency good by feeding it with the inferior fish of the catch. At length all are ranged in their due order, facing outwards, on the gunwale of each boat. And the sight of that array of great ungainly sea-birds—shaking themselves, flapping their wings, gaw-gawing, making their toilets, clearing their throats, looking about them with a stare of stupid solemnity, and now and then indulging in old-maidish tiffs with their neighbors—is quite the strangest of its little class I have ever seen, except perhaps the wonderful penguinry of the Falkland Islands, whereat a certain French philosopher is said to have even wept. Finally, the cormorants are sent off to bed, and we ourselves follow suit.

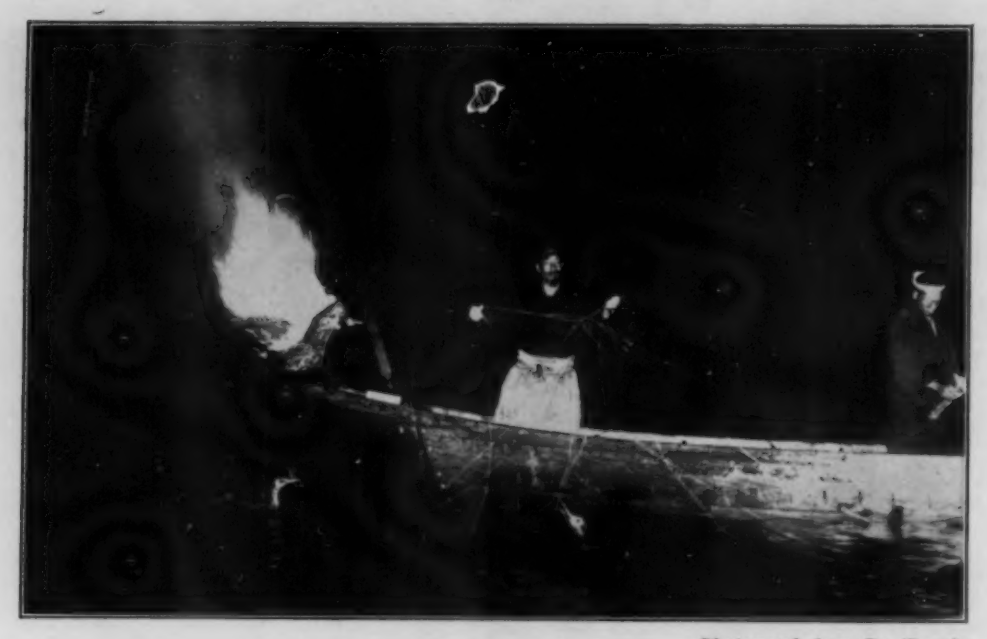
The next account that has come to hand was published in *Die Natur* in 1890. It was written by a person hiding his identity under the initials "K. M."—probably Karl Müller, one of the editors.[8] When translated this sounded very like the account from Chamberlain attributed to Palmer, and careful comparison with Palmer's letter in the London *Times* showed that it is a mere translation, alleged, however, to be made from the *London and China Express*, August 23, 1889. But no such journal is listed in the "Catalogue of the British Museum," or in the "Union List of Serials in the Libraries of the United States and Canada."

In the *Revue Britannique*[9] for May, 1891, is a spirited account of this fishing at Gifu. This also is unsigned but the editor, Pierre Amédée Pichot, in his book (1903) presently to be quoted, says that it is from the pen of an Admiral Layrle. This writer (1891) describes in interesting detail the preparation of the tourists' boat for the fête with lanterns, geishas, servants and refreshments (see Fig. 1). In these boats the visitors embark and follow the boats of the fishermen. This account, apparently that of an eye-witness, differs in some details from that given above and it seems well to reproduce here certain extracts from it. It is stated that when night comes on, preferably one without moonlight, the fishermen make their arrangements as follows:

> In each fishing boat two men begin the preparation of the birds. There are twenty-four to a boat in a large cage. One of the men pulls out a cormorant by the neck and while he holds it thus suspended he strokes it or even tickles it, so that the bird, without any resistance or movement, lets a cord be attached to one of its feet. This cord crossing the stomach ends at the neck in a ring, destined to prevent the passage of a fish down the throat into the stomach [see Figs. 8, 9, 10]. The whole operation [of preparing the birds] lasts about twenty minutes. While this is being done, on a movable crane in front of each boat there is lighted a brazier of wood and straw which sheds a strong but uneven light over the river. The men are at their posts, and the cormorants in the water swim here and there, agitated and nervous among the burning sparks falling from the braziers.

[8] K[arl] M[üller], "Ueber Kormoran-Fischerei in Japan," *Die Natur*, Halle, N. F. Vol. 16 (Vol. 39), pp. 31–32. 1890.

[9] Vol. 67, pp. 51–60. Figures.



—*Photograph from Dr. Kuroda*

FIG. 13. THE HEAD FISHERMAN

AT THE PROW OF THE BOAT HANDLING THE LINES OF THE CORMORANTS. MOST OF THE BIRDS ARE UNDER WATER, BUT ONE IS BRINGING TO ITS MASTER THE FISH IT HAS JUST CAUGHT.

There are only four fishermen to a boat. The one towards the rear steers and controls the boat at his will; the second, armed with an oar [pole?] pushes on the bottom, on other boats or on the rocks in such a way as to send the boat in the right direction. At the two ends, standing in plain sight—the one in front almost in the flames—each of the two master fishermen directs his twelve cormorants, holding the mother cord in which end the twelve small cords attached to the birds.

With everything thus in order (Fig. 11), the fishing boats push off and with the birds drift with the current, closely followed or perhaps preceded by the belanterned boat filled with sightseers, singers and servants, as is portrayed in Fig. 3. The music and songs seem to excite the cormorants and incite them to their duty (Fig. 12). Fig. 13 shows the head fisherman standing in the bow of the boat near the cresset handling the lines of his birds, which threaten to become badly tangled.

These [birds], however, are all old hands at the business. The master follows them with his eye and handles the cords in such admirable fashion that they never become tangled in spite of the many evolutions of the birds—an aquatic pack one might say, but docile and attentive. The birds work on in all the noise and light. They swim, dive, reappear with the head high and the eyes shining, and every time with a fish in their beak. They hurry to get rid of this that they may dive again to take another, or perhaps to play a long time with a catch which they know to be only provisional. The master is there, however, and he does not let them out of his sight. He keeps account of the unusual size of the birds' throats and, without ceasing his watch for an instant, draws quickly in one which he sees is full of booty, seizes him by the neck, hangs him head down, and with a simple tap makes him disgorge instantly his part of the prey into the bottom of the boat [Fig. 7]. Five seconds at the most and the cormorant is thrown back without regard into the water, where humiliated and furious he dives at once to revenge himself on some new fish for the deception of which he himself has been the victim. A new bird is drawn into the boat and the fishing continues, the boats being always carried by the current into the midst of the disturbed feverish birds who dive in the fantastic light of the lanterns and braziers.

All the while the guitars make their music heard and the fishermen continue their encouraging cries. The fishing goes on without pause, obstacle or accident. There is perfect cooperation between birds, fishermen and boatmen.

The fishing ground having been covered, the party breaks up and the tourists return to their hotel, where, in case they did not partake of the *ayu* cooked on board the boat, they are likely to feast on some before retiring. Next morning when the tourists depart, the innkeeper will present them with fans having painted on them the scene witnessed over night. However, if they visit Gifu's chief industry, the factory where paper lanterns are made, such a souvenir may be procured as that shown in Fig. 14.

Pierre Amédée Pichot (editor of *Revue Britannique*) reproduces in his book, "Oiseaux de Sport"[10] the citation from Admiral Layrle previously given. He refigures Layrle's cut of the lantern showing cormorant fishing at Gifu, and also gives (source unknown) the figure showing the boats on a broad stretch of the river at Gifu, reproduced herein as number 6. This same account is also quoted by Alfred Belvallette,[11] who also gives a picture of this fishing drawn by a native artist. This is reproduced herein as Fig. 15.

The references to cormorant-fishing in Japan previously given, and indeed most of those to follow, are from non-scientific men, but there are now to be set out citations from an ichthyologist of high standing, citations which thoroughly corroborate the popular accounts previously quoted and also those to follow.

Dr. Hugh M. Smith, at that time deputy commissioner of the U. S. Fisheries, visited Japan early in the present century to study her fisheries and related industries. As the representative of the

—*From Pichot after Layrle*

FIG. 14. A LANTERN FROM GIFU
SHOWING A FISHING SCENE—PAINTED BY A NATIVE ARTIST.

U. S. Bureau of Fisheries he was made the official guest of the Imperial Japanese Fisheries Bureau and was provided with guides and interpreters who accompanied him on his 5,000 miles of travel. On his return to the United States he published in 1904 and 1905 two papers from which extracts will be made of the cormorant fishing at Gifu.[12]

Dr. Smith states that the chief cormorant fisher at Gifu (Fig. 16) was an expert whose ancestors for many generations (for at least 1,000 years and by tradition extended to 2,000 years) had fished at Gifu. His cormorants had a cord around the lower part of the gullet,

[10] Paris, 1903, pp. 27–35.

[11] "Traité de Fauconnerie et d'Autourserie Suivi d'une Étude sur la Pêche au Cormoran." Paris, 1903, p. 243–250.

[12] H. M. Smith, "Japan, the Paramount Fishing Nation," *Transactions American Fisheries Society*, 33rd meeting, pp. 129–132, 4 figures, 1904; "The Fisheries of Japan," *National Geographic Magazine*, 16: 213–214, 3 figures, 1905.

I am also very greatly indebted to Dr. Smith for allowing me to make free choice from his unusual collection of photographs of fishing with the cormorant in Japan.

—*After Belvallette*

FIG. 15. CORMORANT FISHING
AT NIGHT AT GIFU, FROM A NATIVE SKETCH.

and the lines attached to the whalebone piece of the harness (Fig. 17) were fourteen or fifteen feet long. The boats used were of a special kind almost identical with our long narrow dugout canoes, as may be seen in Fig. 18. He notes that there were four men and sixteen cormorants—twelve handled by the head fisherman and four by his assistant. The fishing grounds covered many miles and were divided into sections which were fished nightly—some sections, however, being set aside as imperial fisheries preserves and no promiscuous fishing being allowed, as noted above.

With a blazing fire of pine wood in the iron cresset overhanging the bow of each vessel, the seven boats drifted broadsided down stream, each being kept in line by the two extra men. The fishing —essentially as described above—went on for several hours, each cormorant filling his pouch and throat fifteen or twenty times.

A spirit of intense enthusiasm fills men and birds alike; and the shouts of the fishermen, the croaking of the birds, the rush of the mountain stream, the splashing and creaking of the paddles, the hissing of the embers as they fall in the water, the weird lights and shadows, combine to make a performance which a westerner is not likely soon to forget.

Dr. Smith was provided with a boat illuminated with lanterns and supplied with refreshments, and from this he witnessed the fishery. Each cormorant boat averaged about 800 fish, and the value of the catch of the seven boats was about $150. The catch was almost entirely *ayu*, the salmonoid fish already referred to.

Next among my notes are those from Ikenoya[13] previously quoted. From him we learn that the Nagara River is seventy to eighty miles long, and navigable for small boats throughout most of its extent, but that the *ugai* (cormorant fishing) is mainly centered around Gifu in three reaches of the river—*kami-ugai*, *naka-ugai* and *shimo-ugai* (upper, middle and lower cormorant-fishing reaches) plus a fourth section reserved for members of the imperial court. The best fishing is had from the middle of May to the middle of October, at which time the young fish are about three inches long, and the sport is carried on at night over each reach of the river alternately. *Ugai* is best carried on on moonless nights, or before the moon rises or after it sets, since the moonlight drives the fish away—causes them to scatter.

The best fishing boats (Fig. 18) are about forty feet long by three wide amidships—wide enough to contain the

[13] S. Ikenoya, "Cormorant Fishing," *Japan Magazine*, May, 1917, pp. 31–32.

bamboo baskets in which the birds are brought by twos to the landing, a basket suspended at either end of a pole. The fishing crew consists of five men—the head fisherman in the bow, two assistants and one boatman in the waist, and the other boatman in the stern. The head fisher looks after the light and handles twelve cormorants, his assistants as learners have four each (making twenty to the boat). The birds have rings around their necks and these must be properly adjusted for each bird. Attached to each ring is a line ten feet long made of cypress bark and held by the fisherman. The birds are encouraged by peculiar cries to dive and catch the fish.

Ikenoya gives an interesting account of how the birds are gotten and trained. They are caught by heavily liming the rocks of their roosting places around Shinoshima in the province of Owari. Good, well-grown cormorants are about two feet in extreme length and weigh about seven pounds each. Their wings are clipped and they are sent blindfolded to Gifu. At first they are very vicious and must be kept tied up. Presently their trainer takes them out on the river every day at noon and allows them (under the leash) to dive, catch and eat one to two pounds of fish each. After about fifteen days of such training and feeding they are taught to catch and disgorge fish. At the end of each daily training period, the birds in regiments of sixteen with three men in charge are allowed the freedom of the river for playing and feeding. While the natural life of the birds is twenty to twenty-five years, under this more or less artificial life they live only about a dozen years.

In 1918, Jihei Hashiguchi published in the *Far Eastern Review* (14: 313–322) an article on the fisheries of Japan with numerous illustrations. Among these is a particularly interesting one (p. 319) labeled "Fishing with Cormorants on the Nagara River, Gifu." The

—Photograph by Dr. H. M. Smith

FIG. 16. THE CHIEF CORMORANT TAMER

AT GIFU ABOUT 1903. NOTE HIS PECULIAR DRESS, WHICH IS DESCRIBED FURTHER ON IN THE TEXT.

combination of pale ink and soft paper gives such a poorly printed picture that it will be impossible to reproduce it herein. Moreover there is no reference whatever in the text to this figure.

In 1919 Jabez K. Stone published an interesting article[14] describing a visit to Gifu with a moving picture man, Ben-

[14] "Cormorant Fishing at Gifu," *Japan*, 8: 5–7, 44, 5 figures.

—*Photograph by Dr. H. M. Smith*

FIG. 17. NO. 1 CORMORANT

WEARING THE WHALEBONE HARNESS WITH THE ATTACHED LINE, AND STANDING ON HIS CAGE.

jamin Brodsky. Brodsky made a series of films (taken at night) depicting this fishing, and Stone illustrates his article with selections from these. His account is very similar to those already quoted, varying only in slight details. The cormorants are trained to fish in groups of twelve. The body of each bird has around it a cord with a bamboo (not a whalebone) handle to which is attached the line of tough fiber which will not easily tangle or form knots. The birds are well trained, and of hundreds on the river at once, each knows its own boat and master. This latter (*U-jo*) keeps the birds up to their work by calling to them what sounds like "Uish."

In March, 1925, there appeared an account[15] of this fishing at Gifu by Lucy Fletcher Brown. Carrying a letter of introduction from a Japanese priest to a Japanese lawyer in Gifu, she was shown many courtesies and, along with the cormorants was inducted into the fisherman's boat, whence she had an intimate view of the proceedings. However, her account differs but little from the others. There were eight or ten boats, each with four men. The fires were of burning pine knots in cages hung on a pole over the water from the prow of each boat and tended by the cormorant master. The head fisherman expertly handled the reins of "fifteen or more cormorants," while others were shut up in baskets. The *ayu* caught were five to eight inches long, and of these as many as seven were taken at one time from the throat of one bird. There are three illustrations in this article, identical with the first three

[15] "Fishing with the Birds [Cormorants] of Gifu," *Japan*, 14: 23-24, 31, 3 figures.

—*Photograph by Dr. H. M. Smith*

FIG 18. A GIFU FISHING BOAT

WITH PROJECTING STEM (WITH CRANE AND CRESSET) AND STERN. AMIDSHIPS ARE FOUR BASKETS CONTAINING CORMORANTS.

in Stone's account quoted above. This recital, while interesting, adds practically nothing new.

The next account of *ugai* at Gifu is the best of all the popular accounts listed herein. Mrs. May L. Cochrane saw things very clearly and describes what she saw so carefully and effectively that considerable quotation will be made from her spirited story in *Asia*, April, 1925 (pp. 301–305).[16] In general she confirms the others, but in certain details differs. Seven boats fished the river the night she was present. The one she was near (presumably identical with the others) was a

> long flat-bottomed fishing boat, which was cleverly joined without nails and resembled an Indian dugout [Fig. 18]. The cormorant master stood at the bow, commanding his birds. His understudy worked in the waist of the craft. One of the boatmen stayed near him [the understudy] in the center, and the other one, at his post near the stern, handled an oar.

The birds were harnessed as previously described. There were twenty-four birds in each boat, twelve handled by the master, four by his assistant, and eight held in reserve. Remark is made on the dexterity with which the master handles his twelve reins, and the description of this is worthy of quotation:

> I saw that between his fingers he held, divided into groups, a number [twelve] of thin strings, which spread out fanwise from his left hand. With his right he kept sorting and dis-

[16] This is done and certain figures are reproduced with the kind permission of the editor of *Asia*.

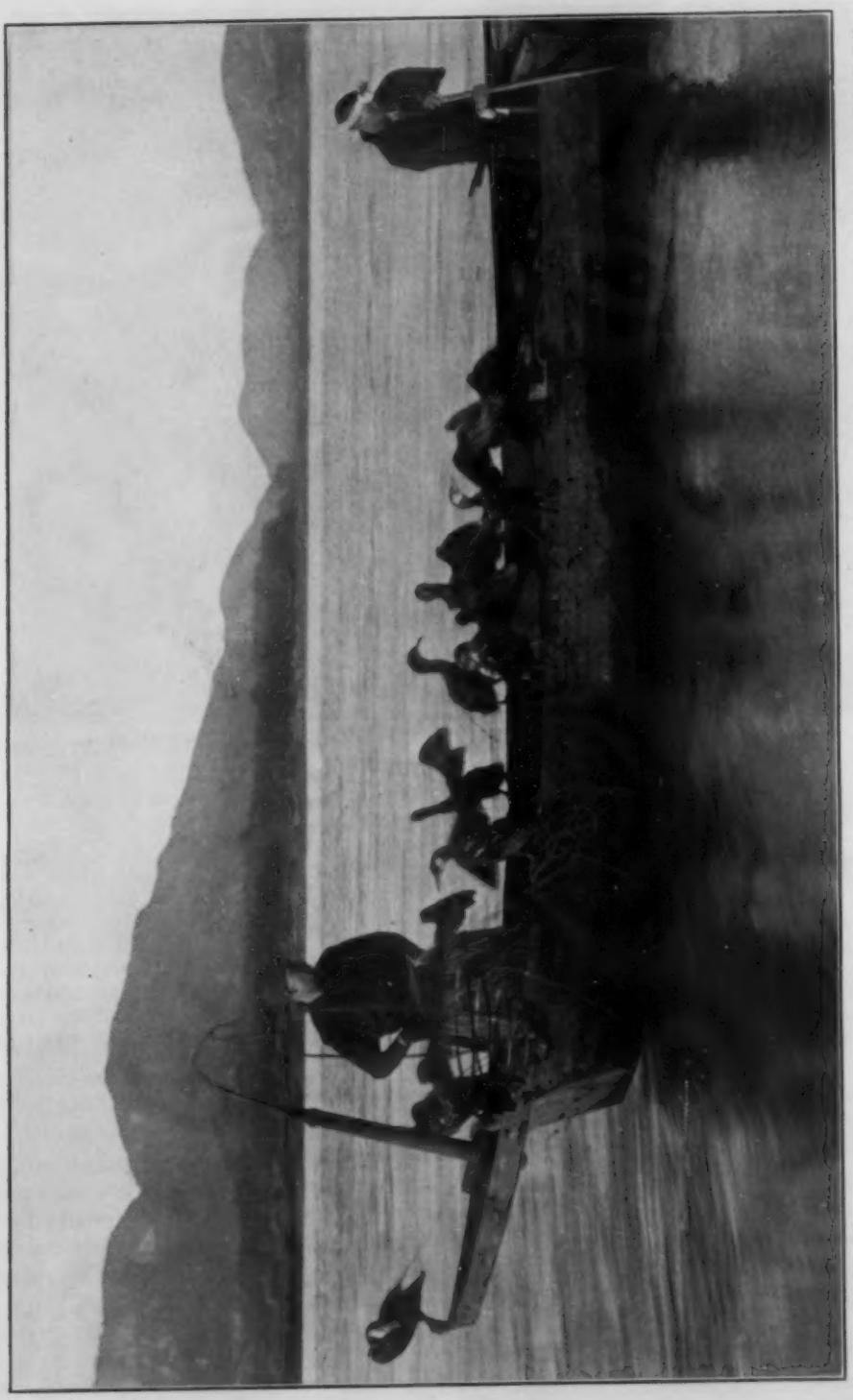


FIG. 19. THE PROW OF THE BOAT —*Photograph by courtesy of Gifu Municipal Office*

SHOWING THE CRESSET, THE HEAD FISHERMAN, THE CORMORANTS ARRANGED IN ORDER ON THE GUNWALES—ICHI-BAN PROUDLY STANDING ON THE TIP OF THE BOW—AND THE BOATMAN PUSHING ON AN OAR OR POLE.

entangling these strings with the dexterity of a trained puppet-master. At the other end of his reins a dozen birds were darting hither and thither in intense excitement and apparently hopeless confusion, plunging out of sight beneath the surface, reappearing unexpectedly several yards away, sometimes floating for a brief fraction of time quiescent as toy ducks riding on the tiny waves of a basin of water.

In addition to handling the twelve birds, the leader keeps up the fire and also directs the movement of the boat, but never for one moment does he lose sight of a single bird. Surely he is as Argus-eyed as he is nimble-fingered. It evidently requires years of practice to acquire the requisite skill to be a cormorant master, and the rank of the fisherman is strictly determined by his skill in handling his lines.

The prey is taken in head first by the birds. Trout are easily handled, but long slender-bodied eels can not be tossed in the air and swallowed head first. One young bird held on to his desperately until the fisherman pulled him in and relieved him of his booty. The cord around the neck allows the passage of small fish, but to be sure that the birds have fed well, at the close of the fishing each is "hefted," and those which show up light in weight are fed on the smaller specimens of the catch.

The cormorants are caught in the summer and fall with birdlime spread on rocks around their haunts. The first caught has its eyelids temporarily sewed up to blind it. Seeing it and hearing its cries, others fly to the rocks and are also caught. The old ones are set free, but the young ones are put in baskets and carried to the fishing grounds. Here their eyes are unsewed and the birdlime washed off, but their wings are clipped to prevent their flying away. Next they are taken out in a boat once a day and (tethered with a cord) are taught to swim alongside the boat. If they continue wild and try to bite their captors, their bills are tied up. After a few days (five or six) as they get used to their trainers, all their bonds are removed. Next these "apprentices" are taken out with trained birds to the river. At first the youngsters merely look on and swim about aimlessly while the trained birds fish. After four or five days, however, the young birds begin to imitate their betters and catch a few fish—probably hunger helps much in this learning period. By the opening of the next fishing season (*i.e.*, about May 15) the young birds begin to fish independently and by the end of two years become expert fishermen.

The most experienced cormorant, the one longest in service, is called *Ichi-ban* —"Number One," and as noted above he demands and is accorded special treatment. His place in the boat is nearest the bow or on it (Fig. 19), and here ready to fish, his value to his owner stands at some $75. Each of the younger and lesser birds knows his place also, and if this has been preempted he makes known his wrongs in raucous shoutings. Fig. 19 shows the birds sitting on the gunwale in the order of seniority.

Mrs. Cochrane concludes her interesting account with a very pleasing incident in which is recounted the means by which the cormorant master keeps up the morale as well as the physical health of his feathered helpers. Since this seems to be an essential part of their training, it will be quoted in full. Figs. 20, 21 and 22 will illustrate the account.

Presently one of the cormorant masters loaded his baskets upon a dugout and pushed off. We followed in his wake to a quiet cove, where the boats were beached and the birds liberated for their daily bath. In a bunch they floated over the water, ducking and diving for their breakfast of minnows and other small fry. Ecstasy over freedom and contact with their native element was expressed in hoarse notes and many giddy episodes. The birds flew up just to swoop down and "skid" along on their tails, with webbed feet well up, spread "full sail," before they alighted to swim. Then for an interval they all beat the water madly with great sweeps of their wings, until the air was

—Photograph by courtesy of Gifu Municipal Office

FIG. 20. FISHING IS OVER

AND THE CORMORANTS ARE LANDED ON THE BEACH. NOTE THE DRESS OF THE CHIEF CORMORANT TAMER AND THE BUNDLE OF CORDS IN HIS LEFT HAND.

filled with fountain sprays, glittering in the morning sun.

Their surprising antics delighted me for a half hour. Then *Ichi-ban* went ashore, and all the other birds followed. He chose a dry, open space among the bushes, turned his back to the sun, spread his wings and fanned them slowly up and down. Forming in two lines directly behind him, all the others imitated his movements. This solemn rite went on ceaselessly and without a sound for at least ten minutes, until all feathers were dry. When some of the young birds started off on a fresh frolic, they had to be forcibly persuaded by the patient cormorant master to return, but Number One walked quietly to his basket and stood waiting to be lifted into it. Apparently he had put aside the frivolities of turbulent youth and now seemed content to sleep away, or blink away, the sunny hours, with a tranquillity and a peace utterly unknown in his wild state. With the philosophy of old age he had accepted, in exchange for his loss of hazardous freedom, sure food and a basket-home among mankind.

In Fig. 20 is shown the boat with the baskets amidships, an assistant and the chief fisherman with eight cormorants on the beach. In his left hand he holds in a bundle the lines, while his right is free to keep them from becoming entangled—just as Mrs. Cochrane has written. In Figs. 21 and 22, the birds are free on the beach, drying their feathers in the sun.

Dr. Nagamichi Kuroda, by imperial edict, went to Gifu early in the summer of 1926 to study the fishing there. Here he apparently stayed some time, for, instead of describing some particular night's fishing, he wrote a carefully considered general article[17] dealing with the birds and the other apparatus used in the fishery. From his informing article, certain matters confirmatory or contradictory of preceding statements will now be given.

[17] "Cormorant Fishing on the Nagara River," *Japanese Magazine*, Tokyo, 16: 303–320. 16 text figures. 1926.

—Photograph by courtesy of Gifu Municipal Office

FIG. 21. FISHING CORMORANTS

ON THEIR CAGES AND ON THE BEACH SPREADING THEIR WINGS TO DRY IN THE SUN. THE YOUNGER BIRDS MAKE MUCH ADO OVER THIS, BUT THE OLDER ONES, LED BY ICHI-BAN, BEHAVE VERY SEDATELY.

The cormorants are of two kinds, the larger or Schlegel's cormorant (*Phalocrocorax capillatus* Temminck and Schlegel), which is most used, and also the smaller or Japanese cormorant called *Kawatsu* (*P. carbo hanedae* Kuroda). The latter dwells in trees, the former among rocks. To catch the larger form, the rocks are limed, and on them as a decoy is placed a captive bird with its eyelids sewed up. Birds caught thus sell at 15 *yen* (about $7.50) on the average. When trained they are worth from 150 to 300 *yen* ($75 to $150).

With the eyelids sewed, the birds are carried to their destination. Here the threads are removed, the wing feathers clipped, the birdlime washed off, and the birds tied with hempen cords are put in the water to swim about the boat. At first they are afraid of their trainers, refuse to fish (even for themselves) and often try to bite the men. In this case their bills are tied up and they are left for some time. When somewhat tamed, their bills are freed and they are taken out on a shoal with tame birds to swim about the boats. Presently they begin to follow the example of the trained birds and so take fish for their own food. Since the cormorants are taken during the summer or fall migration, they get several months' training before the opening of the fishing season in the following May. By this time they begin to work independently but still fear the fire and the noises. It generally takes from one to two full years of training to make a good fisher. The trainer studies the psychology of his birds and grades them accordingly. He gives each bird a name and always addresses it by that name. When fishing is to be done, the birds are lined up on the gunwales of the boat in

—By courtesy of Gifu Municipal Office

FIG. 22. CORMORANTS ON SHORE

DRYING THEIR FEATHERS AND RESTING IN THE SUN. NEARBY ARE THE BASKETS IN WHICH THEY ARE KEPT WHILE AT HOME OR WHILE BEING TRANSPORTED TO AND FROM THE FISHING GROUNDS.

the order of proficiency, each bird knowing its place. If the birds grow lazy and do not want to fish water is thrown on them to make them do so.

During the fishing season and also during early spring and late fall the keep of the birds presents no problem—they are simply taken out on the river and allowed to catch their own provender. This is called *e-gai* or "feed-keeping fishing." However, the tamers watch the birds, "hefting" them from time to time, and turning up the overfed to free them of surplus fish, and encouraging the underweighted to catch more—the quantity of food always being estimated by weight. During the winter, the birds are kept in a fowl room next to the trainer's house, and *Ie-gai* or domestic feeding is practiced in time of storms and when snow and ice prevent resort to the river. At all times the birds after being fed at 10 P. M. are put to bed with their throats tied to prevent regurgitation. They "ruminate" until about 10 A. M. next day when their throats are untied and about 1 P. M. they fetch up the bones.

The best birds are four to eight years old, at which time they are worth 150 to 300 *yen*. Older than eight they begin to slow down in their work, though they can be used up to about fifteen years. The birds are brought to the boats in baskets having a central partition of board, with two "intimate" (*i.e.*, friendly) birds in each half (see various figures above). Sometimes these are male and female, sometimes two females, but always friendly birds are put together—non-friendly quarrel loudly. The night baskets have no partitions and contain two friendly birds only.

So much for the birds; now for the other apparatus used. The boats with their curious prows (shown in Fig. 19) are made of pine boards. They last from four to five years. The boats either

drift down stream or are propelled with oars and poles, while sails are sometimes used in going to the fishing grounds as may be seen in Fig. 23. The cords or reins are made of the fine inner bark of the Japanese cypress, and those used in summer are longer than the winter cords. There are baskets for bringing the birds to the boat and for holding them previously, other baskets for holding the fish, and another box-like basket for holding the pine wood and keeping it dry. However, none of these need be described.

The dress of the chief cormorant tamer is very distinctive and is worthy of a brief description. He is easily recognized by his peculiar head-dress, called *Eboshi*. This is made of hemp, is dark blue in color, and sometimes four feet long. It was formerly worn by old-time nobles, but now wound around the head it is a sign that the wearer is an expert cormorant fisher. It also protects his hair from sparks. His body is clothed in a dark blue cotton coat—*Shozoku*. Over this (seen clearly in Fig. 16) is a plastron of blue cotton cloth, a foot wide and one and a half long, to protect against splashing water. Around his waist is a *Koshimino*, or kilt of dried grass, to protect his legs from water and from the wings and claws of the cormorants while he is causing them to disgorge. These things are shown in Fig. 24. Fig. 25 is from a photograph of the chief cormorant fisherman at Gifu in 1927. He is attired in the dress just described.

The fishing is carried on from May 11 to October 15 on every calm night except full moonlight nights or when the river is turbid and the birds can not see

—*Photograph by courtesy of Dr. H. M. Smith*

FIG. 23. THE FISHING BOATS

ARE GENERALLY ROWED OR POLED TO THE FISHING GROUNDS, BUT IF THE WIND IS FAVORABLE A SAIL IS SOMETIMES HOISTED TO SAVE THE MEN THIS LABOR.

—Photograph by courtesy of the authorities at Inuyama

FIG. 24. THE EQUIPMENT OF A CORMORANT FISHER

a, THE *eboshi*; *b*, THE PLASTRON; *c*, THE CORDS FOR TYING THE CORMORANTS; *d*, THE *koshimino*; *e*, THE COAT. THIS IS THE EQUIPMENT USED AT INUYAMA.

the fish. During the first quarter of the moon the fishing is done after moon-set, during the last quarter before moon-rise. Seven boats are used at Nagara-mura and five at Sijiri-mura. Each boat is manned by a *U-jo*, or chief cormorant tamer, stationed in the bow and handling twelve birds. Amidships is his assistant, called *Naka-udzukai*, who fishes with four to six cormorants. In each boat are also two cormorants held in reserve, and any bird not up to standard before or during the fishing is replaced by a reserve fowl. There are two boatmen—the *Ro-nori* in the stern, and the *Chi-nori* in the waist.

The *U-jo* holds the *Ta-nawa*, or hand rope, made of the inner ends of the twelve cords from the cormorants, takes in and empties the full birds (the larger of whom can hold in the throat seventeen or eighteen fish of four to five inches in length), and feeds the fire. The assistant tends his birds and the two boatmen cause the boat to follow the cormorants. Often the boats drifting down stream change places so that the best places may be equally shared.

CORMORANT FISHING IN THE CHIKUGO AND YABE RIVERS AT NIGHT FROM BOATS

In Chikugo province, Fukuoka prefecture, in the northern part of the southern large island, Kyushu, Temminck's cormorants are caught by covering their rocky roosts with birdlime in which human hair has been worked to make it more tenacious. This, it should be noted, is a distinct improvement over the method heretofore recorded. The birds are caught mainly by their tails and wings. The first caught are used as decoys for taking others. The fishing on the rivers named is done only at night but from boats slightly smaller than those used on the Nagara. These boats have only two men each as against four or five on the Nagara, one boatman and a cormorant tamer who handles only seven or eight birds contrasted with

twelve at Gifu. The season is the same as on the Nagara. There are ten boats on the Yabe, where the fishing is more thriving than on the Chikugo.

Fishing at Fukuoka City in the Naka and Sawara Rivers at Night and in Daytime by Wading

Here was formerly carried on (abolished about twenty-five years ago) a very unusual kind of cormorant fishing. For knowledge of this we are indebted to Kuroda (1926). Let us hear first what he says of the night fishing.

This fishing was done only on moonless nights. On moonlight nights the fishing was deferred until the next day and carried on in daylight. Each of the fishermen waded, carried a blazing torch, and fished his cormorants from the lower reaches of the river to the upper. Preceding the fishermen and the cormorants were cast-net throwers (*U-saki-uchi*) who caught the frightened fish as they fled upstream. These net-casters were sometimes hurtful to the cormorants, but were generally used, because with their help larger catches were made. The cormorant rope spoken of in the next paragraph naturally could not be used at night.

Kuroda says that the daytime fishing was carried on in the very outskirts of the city itself. Here follows his account.

> Seven or eight cormorant tamers made a group, and went [wading] up the river, handling their cormorants, with one fowl each on his left hand and a hand rope in his right hand. The eight fishermen advance on their way [by wading] abreast, and one of them who stands nearest to the bank and in the deepest place ties a *U-nawa* or cormorant rope (which is a long rope, made of straw) on one of his legs and the other end of this cormorant rope, which

—Courtesy of Gifu Municipal Office

FIG. 25. A PHOTOGRAPH OF SUB-LIEUTENANT YAMASHITA

A CHIEF CORMORANT FISHER AT GIFU IN 1927, WEARING THE OFFICIAL DRESS OF HIS OFFICE. HE IS CAUSING A CORMORANT TO DISGORGE ITS CATCH.

—*Photograph by Dr. J. O. Snyder*

FIG. 26. A GROUP OF WADING CORMORANT FISHERS

THESE MEN PLY THEIR TRADE ON THE SHALLOW NON-NAVIGABLE STREAMS. NOTE THE BASKETS FOR HOLDING THE FISH.

crosses the river, is held by a boy on the other side of the river, the shallower part, and dragged by him on his shoulder along the bank.

Sweet-fish going down the river are frightened and checked by this rope and forced to run up, turning their direction, which facilitates the cormorants to swallow them. One cast-net thrower or two take their positions ahead of the group of the cormorant tamers. . . . Unless these net throwers are employed the fishing has no success. The *U-jo* carry *Koshi-tebo* or loin baskets about their loins [Fig. 26], and when the fowls have swallowed some ten fishes, large or small, they make them expel the fish into the *Koshi-tebo*.

From this description, the function of the cast-netters is plain as is that of the cormorant rope—which is necessarily not used at night. This last device is, by the way, well known to the South Sea islanders, who utilized it for herding fish in precisely similar fashion. The cormorants used at night are not fed until early next morning, while the daylight fishers are fed immediately the fishing (lasting two to three hours) is over. The birds are fed but once a day and are only employed after they have vomited out the undigested fragments of bone from the preceding meal.

Here then we have an entirely new form of cormorant fishing, boats being dispensed with and the fishermen wading along behind the cormorants. Cast-net fishermen are used as auxiliaries, and in the daytime the fish are herded along by the device of the "cormorant rope." This fishing is of course a purely commercial transaction. Such a group may be seen in Fig. 27.

CORMORANT FISHING NEAR TOKYO IN THE SAGAMI (BANU), TAMA (ROKUGO) AND ARA (SUMIDA) RIVERS AT NIGHT AND IN THE DAYTIME BY WADING

These streams enter into the Atlantic Ocean, and the cormorants used, the

Kawatsu (the smaller or Japanese birds), are caught mainly on the coasts of Tokyo Bay. The fishing, which is carried on both at night and in the daytime, was (so far as I know) first described by Jouy in 1888.[18] He visited the Banugawa (about twenty-five miles from Tokyo) in 1886, and saw this fishing on a moonlight night ("a bad night for fishing"). The river was twenty-five to fifty yards wide and had a swift current. Here follows Jouy's account.

The man with his bird was waiting for us on the stony bed of the river, with his torch of pine-fat burning brightly. The bird (*Phalacrocorax* sp.) was very tame, and sat perched on a rock close by. A cord was tied pretty tightly around the lower part of the throat and between the shoulders, from which was attached a piece of bamboo (having a swivel at each end), long enough to extend beyond the bird's wings and prevent fouling of the cord while the bird was put in the water. The man carried a basket at his side to put the fish in, and a sort of apron in front to hold pine chips for the light. The lantern was a wire cage or basket placed on the end of a long bamboo pole. This, with the cord attached to the bird, which gives him a range of about twenty feet, is held in the left hand, the right being employed in guiding the bird, replenishing the fire and taking the fish.

Everything being ready, the fisherman takes the torch in his left hand, and clasping the cord, to which the bird is attached, wades out into the stream, the bird following him and, after performing a hasty toilet, dipping his head and neck in the water and preening himself, begins the business of the night. The fisherman holds the fire directly in front and above the bird's head, so that it can see the fish in the clear water. The bird seems to be perfectly fearless, and as he comes up sparks

[18] P. L. Jouy, "On Cormorant Fishing in Japan," *American Naturalist*, 22: 1–3, 1888.

—*Photograph by Dr. J. O. Snyder*

FIG. 27. FISHING WITH CORMORANTS BY WADING

U-JO, WITH CORMORANTS, AND TWO HANDLERS OF THE NET.

—*Photograph by Dr. J. O. Snyder*

FIG. 28. THE CORMORANT TAMER

STANDS AT (OUTSIDE?) THE NET, THE TWO NETTERS DRAW THE NET IN THE FORM OF A TRIANGLE WITH THE CORMORANT NEAR THE APEX.

of fire are constantly falling on his head and back.

The fishing is done up-stream, the man finding it all he could do to keep pace with the bird as the water surges up nearly to his thighs; in fact, it was hard work for us on shore to scramble along among the rocks in the uncertain light and watch the bird at the same time.

The bird dives, swims under water for eight or ten yards, comes up and is down again, working very rapidly and constantly taking fish. When the fishes are small the bird is allowed to retain two or three in his throat at a time, but a fair-sized fish is immediately taken from him and put into the basket.

During a space of half an hour fifteen fishes were taken, which was pronounced a good catch considering the brightness of the night. The largest of these fishes, which were all of the same species, were nine to ten inches in length, and having been taken immediately from the beak of the bird were scarcely bruised. The largest and best of these we had the next morning for breakfast, the others we gave to our friend, the cormorant, who was kindly assisted by his master to get them past the cord which constricted his throat so that he could not otherwise have swallowed.

The birds are trained especially for the work, and do not fish in the daytime. Our bird was two years old, and was considered a very bright and active fisher, having on good nights, fishing all night, caught as many as four hundred fishes—three hundred was considered a fair night's work. Only calm nights are available, and the darker the better.

That veteran ichthyologist, David Starr Jordan, describes in the following lively fashion daytime fishing with the birds in the Tamagawa or Jewel River, about ten miles east of Tokyo.[19]

[19] David Starr Jordan, "Fishing for Japanese Samlets [with Cormorants] on the Jewel River," *Outing*, 40: 23–25. Figure. 1902.

At the farmhouse . . . we send for the boy who brings our fishing-tackle.

They come waddling into the yard, the three birds with which we are to do our fishing. Black cormorants they are, each with a white spot behind its eye, and a hoarse voice, come of standing in the water, with which it says *y-eugh* whenever a stranger makes a friendly overture. The cormorants answer to the name of *Ou*, which in Japanese is something like the only word the cormorants can say. The boy puts them in a box together and we set off across the drifted gravel to the Tamagawa. Arrived at the stream, the boy takes the three cormorants out of the box and adjusts their fishing-harness. This consists of a tight ring about the bottom of the neck, of a loop under each wing, and a directing line.

Two other boys take a low net. They drag it down the stream, driving the little fishes—*ayu*, *zakko*, *hai* and all the rest—before it. The boy with the cormorants goes in advance. The three birds are eager as pointer dogs, and apparently full of perfect enjoyment. To the right and left they plunge with lightning strokes, each dip bringing up a shining fish. When the bird's neck is full of fishes down to the level of the shoulders, the boy draws him in, grabs him by the leg, and shakes him unceremoniously over a basket until all the fishes have flopped out.

The cormorants watch the sorting of the fish with eager eyes and much repeating of *y-eugh*, the only word they know. The *ayu* are not for them, and some of the kajikas and hazes were prizes of science. But *zakko* (the dace) and *hai* (the minnow) were made for the cormorant. The boy picks out the chubs and minnows and throws them to one bird and then another. Each catches his share "on the fly," swallows it at one gulp, for the ring is off his neck by this time, and then says *y-eugh*, which means that he likes the fun, and when we are ready will be glad to try again. And no doubt they have tried it many times since, for there are

plenty of fishes in the Jewel River, *zakko* and *hai* as well as *ayu.*"[20]

Kuroda (1926), in his authoritative paper previously cited,[17] writes of cormorant fishing in the district in which are found the three rivers referred to above. After noting that fishing in these streams is carried on only in the daytime, he goes on to say that:

. . . one chief cormorant-tamer and two assistants make a group [Fig. 27], but sometimes two chief tamers, two assistant-tamers and one *Haki-kago* (carrier of a basket for sweet-fish caught), form a group. In the former instance the *U-jo* himself carries a *Haki-kago*, and in the latter there is a man specially charged with carrying it with him. The *U-jo* puts his cormorant on his left hand and enters the river, a hand-rope in his right hand, and fishes going upstream, but sometimes he fishes going down the river. [In this case] The fowls are handled so as to swim down the river, following the current of the water.

At the beginning two assistants, who stand at each end of a net with a chief cormorant tamer at the center [Fig. 28] drag the net, long and slender . . . with many weights hanging on its edge and with hand-ropes . . . on both ends. Those two assistants take care that the *U-jo* or chief tamer [standing below the net?] steps on the lower edge of the central part of the net so as not to let it drift away. Within this enclosure the cormorant is immediately set free. The net is stretched so as to form a triangle by the force of the current. The two assistants narrow the net by hauling on both ends from right and left, and go up the river against the current of the stream. On the part of the *U-jo*, he stands at the same spot without moving even an inch until the fishing [in that pool?] is over [Fig. 28]. When the fowl has swallowed many fishes he makes it expel them, by drawing it near to himself, and then immediately lets it free again in the water. This method is repeated several times, and when the two assistants approach the chief tamer the sweet-fish in confusion run up towards the center of the net, swimming against the current of the river, and it is at

[20] This account is republished in Jordan's "Guide to the Study of Fishes," New York, 1905, vol. 2, pp. 116–118. It is referred to in vol. 1, pp. 333–335, and two figures from J. O. Snyder are shown. It is also found in his latest book, "Fishes," New York, 1925, pp. 142–144, Figures 107 and 108.

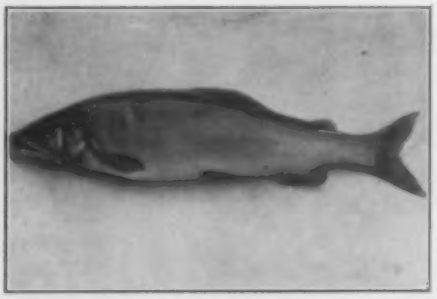
—Sketch by Dr. J. O. Snyder

FIG. 29. DIAGRAM

SHOWING THE NET HELD BY THE TWO NETTERS (1 AND 2), AND THE CORMORANT MASTER (3) WITH THREE BIRDS IN THE ANGLE OF THE NET.

FIG. 30. DIAGRAMMATIC SKETCH

BY DR. J. O. SNYDER TO SHOW HOW THE HARNESS IS FASTENED TO AND AROUND THE CORMORANT'S NECK AND WINGS.



—Photograph by courtesy of Dr. Kuroda

FIG. 31. THE SWEET-FISH, THE *AYU* OR *AI*

SHOWING THE MARKS WHERE IT WAS CAUGHT BY THE BEAK OF THE CORMORANT. ITS SCIENTIFIC NAME IS *Plecoglossus* (PLAITED TONGUE) *altivelis* (HIGH SAIL), AND IT IS A MEMBER OF THE FAMILY SALMONIDAE.

this moment that the cormorant can swallow many fish. Thereupon the fishing comes to a close. This mode of fishing can not be applied to a pool which is too deep, it being confined to such a depth as a man can keep standing in.

The distinction between fishing upstream and down, the position of the net with regard to the *U-jo* and the cormorants, whether the birds swim up or down and catch the fishes going against or with the current—all these matters are not very clear, but in any case Kuroda's own words are given. The matter, however, is definitely set out in a communication from Professor J. O. Snyder, who saw this fishing in the Tama River in 1900. His letter with his illustrative diagrams (Figs. 29 and 30) is reproduced herewith with his permission.

In so far as I am able to recall, the practice of fishing with cormorants is carried on in only a few localities in Japan—I know only of Lake Biwa, the Nagarakawa province of Mino, and on the Tamagawa, which is within easy reach of Tokyo. The pictures [Figs. 26, 27, 28] were made at the Tamagawa in 1900. At Lake Biwa and the Nagarakawa (Nagara River) fishing is done at night with torches; at the Tamagawa (Tama River) it is done by daylight. At the latter place the fishermen wade in the stream, driving the fish by means of a fine-meshed net with leads on the lower edge and floats above. The net is drawn seine-fashion, a fisherman at either end [Fig. 29], while the man who manages the birds wades near the middle of the net, which drags against his legs. The birds work back and forth within the angle of the net. Each bird is held by a leash, a long line made of fiber from the bark of a tree, the *Hinoki*. This leash is attached in turn to a strip of whalebone about one foot long. This serves to keep the leash from entangling the wings or legs of the bird. The whalebone is attached to a harness or hempen cord, one strand passing around the neck, and one backwards and around each wing, meeting in front. The neck strand may be tightened to constrict the pouch. This harness is used at both the Nagarakawa and Tamagawa fisheries [Fig. 30].

I believe that cormorant fishing is a sporting, rather than a commercial affair. At the Nagarakawa the fishermen may be engaged along with a sort of houseboat where meals are served, the little *Ayu* furnishing a most delicious dish. Music, geisha girls and various decorations often lend a festive air to the occasion.

With this very pertinent first-hand description, I close the accounts of "Cormorant Fishing in Japan."

ASPECTS OF NUTRITION AND METABOLISM IN CHINA

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THIS report is an attempt to summarize the present state of knowledge on the nutrition and metabolism of the Chinese. China presents the interesting situation of a people who have lived in almost complete isolation, whose dietary habits therefore must represent definite responses to definitely local stimuli or racial traits. And the length of time involved has brought China more nearly to a state of economic and nutritional equilibrium than can ordinarily be attained. The adjustments which the human mechanism has made to these influences present interesting topics of study. Moreover, the Chinese people are sufficiently numerous and homogeneous that a reliable biochemical average is easily possible.

Some of those who first came in contact with China's nutrition problem expected to find a mechanism which not only operated on an entirely different intake level, but which also involved fundamental differences in the metabolic process such as might characterize a distinct species. In this direction there has been disappointment. The first studies, begun a little over ten years ago, were concerned with a systematic examination of food materials and their analysis. It was shown that the food materials of the Orient were quite similar to those of the Occident, apart from one or two items such as the soy-bean which China had been led by her economic situation to exploit to a peculiar degree.

Certain characteristics of the food intake are shown in the accompanying Tables I to III. The division into North China and South China is a well-recognized one. Climate, habits of life and agricultural conditions differ greatly in these two areas. The figures for North China are averaged from the diets of about 1,500 individuals from middle-class families, the dietary records for each individual or family extending over periods of several weeks or more. Some of these data were gathered by the author in the Chee-loo University laboratory; the remainder include those reported by Wu and Wu[1] in Peking. The

TABLE I. CHINESE DIETARIES.

COMPOSITION IN PERCENTAGES BY WEIGHT

	North China	South China	United States
Cereals	57.0	59.7	25
Legumes	7.8	18.2	
Vegetables and fruits	27.1	21.0	20
Sugar and starch	0.2	0	14
Fats and oils	0.8	1.1	
Meat and fish	3.9	0	18
Eggs	0.5	0	5
Milk and cheese	0	0	15
Other foods	2.7	0	3

TABLE II. CHINESE DIETARIES.

INTAKE OF TOTAL FOOD, PROTEIN, FAT, CARBOHYDRATE AND CALORIES PER MAN PER DAY

	North China	South China	United States
Total food (gms)	1188.0	1303.0	
Total protein (gms)	86.4	67.1	106.0
Total fat (gms)	34.1	27.2	
Total carb. (gms)	537.0	604.9	
Total Calories	2794.0	3008.0	3256.0
Calcium (gms)	0.337		0.740
Phosphorus (gms)	1.178		1.630
Iron (gms)	0.0187		0.0179
Average weight of man (kilos)	60.0	54.0	70.0

[1] H. Wu and D. Y. Wu, *Chin. J. Physiol. Rep. Ser.* 1: 135, 1928.

TABLE III. CHINESE DIETARIES.

PERCENTAGE DISTRIBUTION OF PROTEIN AND ENERGY AMONG DIFFERENT GROUPS OF FOOD MATERIALS

	North China		South China		United States	
	Pr.	En.	Pr.	En.	Pr.	En.
Cereals	75.2	83.3	84.2	91.9	37.3	38.2
Legumes	10.6	3.9	6.8	1.2	10.5	12.1
Vegetables and fruits	4.5	2.9	9.0	2.8		
Sugar and starch	.....	0.5	.....	0	0.1	10.1
Fats and oils	.....	3.5	.....	4.1	0.3	10.3
Meat and fish	8.1	4.8	0	0	35.3	19.0
Eggs	0.8	0.2	0	0	4.6	1.8
Milk and cheese	0	0	0	0	11.6	8.1
Other foods	0.8	0.9	0	0	0.3	0.4

figures for the American diet are taken from Sherman.[2] The data for South China are reported by Powell,[3] and are for day-laborers; the day-laborer represents an extreme rather than a middle-class average. The most outstanding feature of these tables is the high consumption of cereals (wheat bread in North China and steamed rice in South China), the absence of dairy products, the small amount of meat consumed and the low values for total protein.

Observations reported elsewhere[4] on Chinese dietary habits show how greens, raw vegetables, sprouted soy-beans, short-time cooking, are some of the qualitative devices which blind experimentation has led the Chinese to employ to supply vitamines and similar essentials. Certain districts have reverted to a mixture of cereals rather than depend on a single vegetable protein, apparently with profit. Abundance of roughage is characteristic of the dietary; constipation and the use of pills are almost unknown.

[2] H. C. Sherman, "Chemistry of Food and Nutrition," 1926.

[3] M. N. Powell, *Chin. J. Physiol. Rep. Ser.* 1: 129, 1928.

[4] W. H. Adolph, *Amer. Food J.*, 20: 441, 1925.

The value for protein though low is in effect still lower when it is remembered that the oriental diet is a very bulky diet and that the coefficient of digestibility of protein is lowered accordingly. Atwater, quoted by Sherman,[2] gives 92 per cent. as the degree of digestibility for protein in the ordinary American mixed diet. Oshima[5] finds 78 per cent. for the more bulky vegetarian diet, while McCay,[6] studying the bulky rice diets of India, shows that a consumption of 766 grams of rice (dry weight) per day will lower this coefficient to 52 per cent. The South China diet here reported is such a rice diet; in other words, 67.1 grams of ingested protein per day becomes an effective 35 grams per day! No experimental data on the coefficient of digestibility of protein in the Chinese vegetarian diets have as yet been reported. We are hoping to secure such data.

There has been too great a tendency on the part of the China enthusiast to extol rather than sanely to evaluate. It is commonly asserted that the mass of the Chinese people live just on the fringe of starvation, or just within the fringe of an animal existence. This is true, and while it is interesting to note how China by a sort of blind experimentation has selected just those food materials which under prevailing economic conditions most effectively meet nutritive needs, the Chinese people have been too often complimented on their ability to thrive on this fringe of existence. Attention has been called to the tall, apparently robust physique of Shantung, and the world traveler reminds us of limitless capacity for toil and labor, but the fact remains that the mass of the people are dangerously underfed. Nutritional science today is interested in the optimum metab-

[5] K. Oshima, "Japanese Investigations on Nutrition of Man," 1905.

[6] D. McCay, "The Protein Element in Nutrition," 1912.

olism, not in mere existence, and the problem before the Chinese people is one of improved growth and vigor rather than mere maintenance of equilibrium.

Famines in China show definitely that the Chinese diet allows no emergency reserve, for a slight lowering of the quality and quantity of food intake produces immediate disaster. Careful observations on athletic squads, school kitchens and hospital groups have shown how intimate is the relationship between food intake and health. Overwork among students manifests itself, not as nervous breakdown, but as tuberculosis. One director of a large nursing school found that she could reduce the annual tuberculosis casualties among her student nurses either by improving the food, or by reducing the number of hours of work per day. Either method was equally effective. Wu and Wu[1] have fed typical Chinese and typical American diets to laboratory rats and have demonstrated the superior growth-promoting properties of the latter type of diet.

Famines in China have furnished excellent opportunities for observing dietary requirements. In the famine of 1921, one of the relief commissions set out definitely to determine the minimum amount of food for a living diet. It was determined that a daily ration of ten ounces of mixed cereal and soy-bean plus four ounces of vegetable and a small amount of salt, yielding a total of 1,200 Calories, would support a man if he did no work. Seventeen men were sustained on this diet for ten weeks, weighings being taken every few days. The report is that the men seemed quite content on this diet and looked well. Others on the same diet but who worked during this period lost heavily and had to receive a double ration. These data then were used as the basis for a relief ration for some tens of thousands of people. Such data almost approach the conditions of a basal metabolism test. In this same famine the American Red Cross employed an average of 20,000 men in road construction work for seven months; they were placed on a well-balanced diet furnishing about 2,800 Calories, the diet being composed essentially of mixed cereals with fresh vegetables.[7] At the same time in an adjoining area a similar group were fed a similar cereal ration without the fresh vegetable admixture. The second group were observed to be lacking in energy; their general health was poor, and they became an easy prey to contagious disease. These data were as convincing as any present-day experiments on laboratory rats, and in addition the experiment involved a large number of individuals. Lack of transportation in China, as well as the existence of natural division lines, means that it is possible to set off large areas for experimental purposes, and in times of famine thousands of people become available *en masse* as experimental subjects.

The tables presented show a very small meat intake. Table IV indicates

TABLE IV

MEAT CONSUMPTION OF THE PRINCIPAL COUNTRIES OF THE WORLD (GRAMS PER CAPITA PER DAY)

United States	149
Great Britain	130
France	92
Belgium and Holland	86
Austria-Hungary	79
Russia	59
Spain	61
Italy	29
Japan	25
China (North)	15

the place which meat occupies in the diets of the nations. The figure for China is estimated from trade reports; data for the other countries are those quoted by Robertson.[8] The importance

[7] H. C. Embrey, *Am. J. Publ. Health*, 12: 514, 1922.

[8] T. B. Robertson, "Principles of Biochemistry," 1924.

of meat may still be a moot point, but the experience of the Chinese people would seem to confirm the thought that a vegetarian diet is at least not impossible. Their present food habits have certainly not been greatly altered for at least 1,500 years, and possibly not for 3,000 years. There is no room here for philosophizing on the place of meat in the diet. One who has been in contact with the nutrition problem in the Orient willingly subscribes to the observation that meat diet seems to be characteristic of the most aggressive peoples of the world.

The figure for calcium (Table II) is low. The amount may not be low enough to cause disease, but like many of the other dietary factors it seems to be just low enough to prevent optimum growth. Public health authorities report the following as the common diseases of China: tuberculosis, beri-beri, xerophthalmia, rickets and osteomalacia, while those infrequent are: appendicitis, gastric ulcer, gout, rheumatism, gallstone and obesity. Note that most of these are recognized as nutritional disturbances.

Interest in the basal metabolism of the oriental peoples was stimulated by an experiment on a few Chinese women students in an American institution which showed a lower basal metabolic rate.[9] Takahira[10] in Japan had concluded that the basal metabolism of Japanese and Americans is essentially the same. Data gathered by Earle[11] for China, as yet incomplete, indicate that the basal metabolism for the Chinese may be slightly lower. Ling,[12] studying blood constituents, finds that the mean for North China exhibits only very slight differences from the normals for Americans. The blood pressure of Chinese would seem to be lower than the normal in the United States.[13] The Chinese as a rule excrete less chlorine than Westerners.[14] Metabolism studies show that higher amounts of creatinine and uric acid are excreted:[15] the higher excretion of uric acid may be related to the tea habit, while in South China at least the amount of ammonia nitrogen excreted is exceptionally high.[16] But South China is really subtropical, and the whole subject of metabolism in the tropics is still unsolved. Among the most interesting data being collected are those which show how the blood pressure of the American moving his residence from the United States to North China approaches the lower Chinese norm.[17] The basal metabolism for Westerners in South China[11] is apparently lower than the recognized American and European standards.

Dietary and metabolic habits must be either inherited or environmental. While many data still remain to be gathered, evidence so far points to environmental factors as the influential ones. South China and North China present distinct types of climate, and when the southern Chinese emigrates to North China and finally adopts the food habits of North China, which incidentally he does with reluctance, his sons begin to approach in stature and weight the larger standards of North China.[17] Studies on the Japanese who have emigrated to the United States[18] show that

[9] G. MacLeod, E. E. Crofts, F. G. Benedict, *Am. J. Physiol.*, 73: 444, 1925.

[10] H. Takahira, "Progress of the Science of Nutrition in Japan," p. 11, 1926.

[11] H. G. Earle, *Chin. J. Physiol. Rep. Ser.* 1: 59, 1928.

[12] S. M. Ling, *Chin. J. Physiol. Rep. Ser.* 1: 119, 1928.

[13] C. L. Tung, *Chin. J. Physiol. Rep. Ser.* 1: 93, 1928.

[14] B. E. Read and S. Y. Wong, *Phil. J. Sc.*, 22: 127, 1923.

[15] S. Y. Wong, *Chin. J. Physiol. Rep. Ser.* 1: 123, 1928.

[16] J. A. Campbell, *Bioch. J.*, 13: 239, 1919.

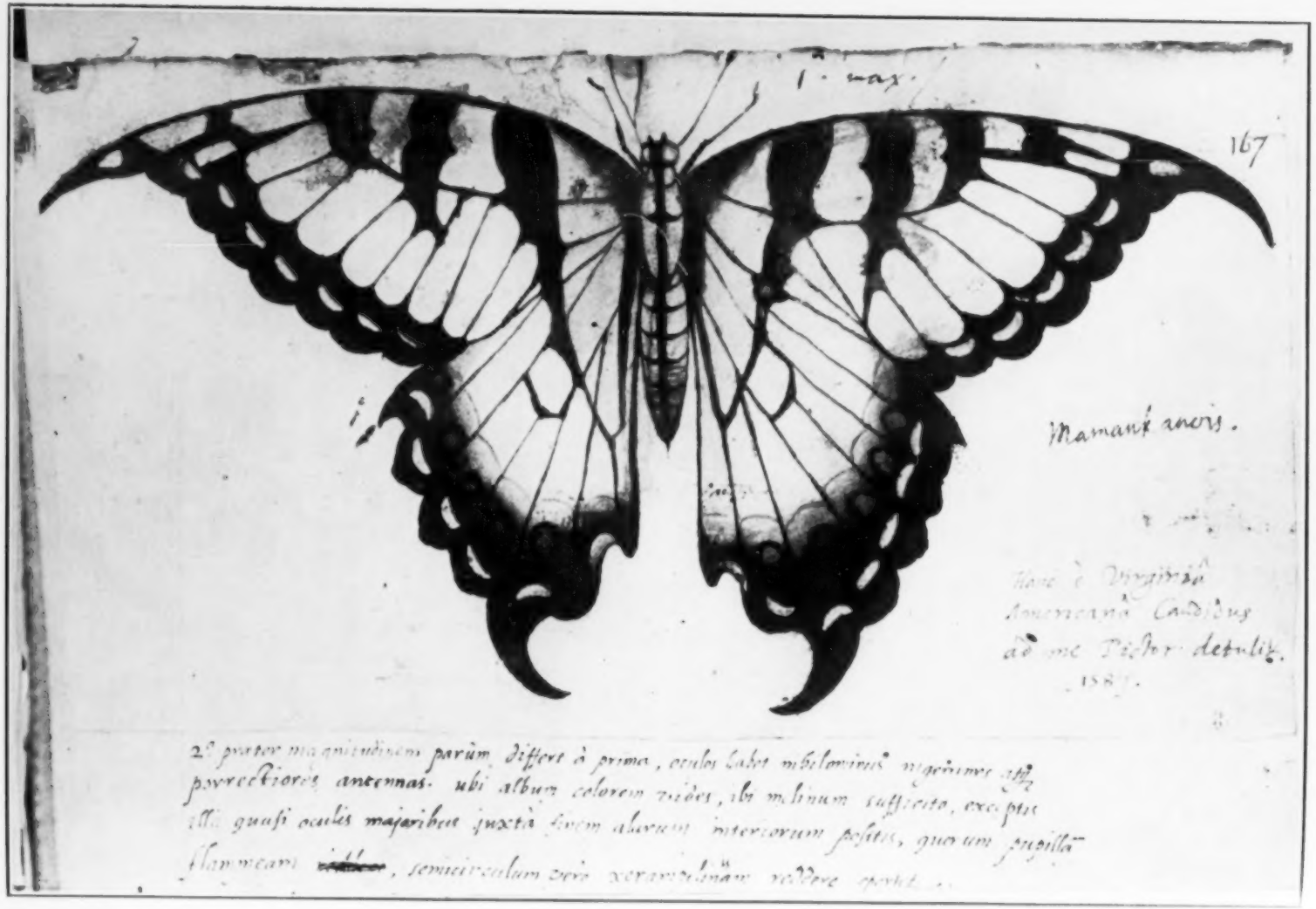
[17] H. Necheles, *Chin. J. Physiol. Rep. Ser.* 1: 80, 1928.

[18] K. Kanzaka, *Annals Am. Acad. Pol. Soc. Sci.*, 83: 88, 1921.

the new environment of food and climate is producing a larger physique. Southern Chinese who emigrated to Hawaii are found to have attained a greater average height after several generations in the new environment.[19] There seems to be general agreement that the different races which make up the population of the United States now metabolize on the same plane, and that so-called racial metabolic traits, if there were any, have quite disappeared. There may even be an inherited racial difference between the northern Chinese and the southern Chinese, but it would appear to have no influence on the metabolism of the organism equal to that of climatic environment and dietary habits.

In conclusion, dietary studies in China indicate wide-spread conditions of undernutrition. Climate and environment in turn seem to have produced a temperament which accommodated itself to a low protein consumption and to a lowered metabolism generally. A type of blind experimentation has aided the Chinese people in reaching probably the best solution of a bad situation.

[19] V. B. Appleton, *China Med. J.*, 40: 259, 1926.



2ª præter magnitudinem parùm differt à prima, oculos habet nibilominùs nigerrimos, & porrectiores antennas. ubi album colorem videbis, ibi nullum sufficiens, excepto illi quasi oculis majoribus juxtà finem alarum interiorum positis, quorum pupillæ flammeam [illegible], semicirculum verò versus exteriorem videbis esse.

THE FIRST PICTURE OF AN AMERICAN BUTTERFLY

By Dr. W. J. HOLLAND

CARNEGIE MUSEUM, PITTSBURGH, PENNSYLVANIA

On the plate we give a photographic reproduction of the very first drawing of an American butterfly made by the hands of man. It fortunately still exists in the library of the British Museum in Bloomsbury, London. To the trustees of that library I am indebted through the kind intervention of my friend, Captain N. D. Riley, of the Natural History Museum in South Kensington, for the privilege of being able to reproduce it.

While the picture itself possesses great interest, the inscriptions on the right side of the plate are even more interesting. These have never before been published. The lower inscription is as follows:

Hanc è Virginia Americana Candidus
ad me Pictor detulit, 1587.

Literally translated it is, "Candidus, the Painter, brought this to me from American Virginia, 1587." The demonstrative pronoun "hanc" being feminine, the ellipsis must be that of a feminine noun. This might be "rem" = *thing*, or "picturam" = *picture*. If the writer had used the masculine "hunc," it might mean "papilionem" = *butterfly;* if he had used the neuter "hoc" it might mean "specimen." The use of the feminine, taken in conjunction with the use of the word "*Pictor,*" leaves no doubt that the writer of the inscription meant to designate the very *picture*, or identical *thing*, upon which he was writing, as having been brought to him from "American Virginia" in 1587.

The word "Candidus," given as the name of the donor, is good Latin for *White*. The inscription thus rendered reads: "White, the painter, brought this picture to me from American Virginia, 1587." Thereby hangs a tale.

The inscription recalls the story of the first attempt made by Englishmen to establish a colony in the New World.

Sir Walter Raleigh, having received from Queen Elizabeth a patent for colonization, sent out Philip Amidas and Arthur Barlowe in 1584 to seek a suitable place at which to locate a colony. They soon returned with a glowing account of what is now the coast of North Carolina. At that time the whole Atlantic coast of North America north of Florida was called Virginia in honor of "The Virgin Queen." In fact, some of the early writers speak of "the continent Virginia." On June 9, 1585, one hundred and eight colonists under Ralph Lane sailed from Plymouth in seven small vessels. The commander of the fleet was Sir Richard Grenville. The colony was landed at the north end of Roanoke Island on August 17. A week later Grenville sailed on his return to England. In the following year on June 19 the colony, half starved and in fear of their lives from hostile Indians, sailed for England in the fleet of Sir Francis Drake, which had appeared at Roanoke. Only a few days after these first colonists had set sail on their return Sir Richard Grenville again arrived at the spot with provisions and more colonists. Only fifteen of those whom Grenville brought out on this second expedition consented to remain. Grenville again returned to England. Raleigh resolved to send a third body of colonists. John

Fiske in his "Old Virginia and Her Neighbors," relating the story of this adventure, says: "John White, a man deft with water-colours, who had been the artist of Lane's expedition, was their governor." With White went his daughter and her husband, Ananias Dare, who helped in the care of the party. They arrived at Roanoke Island on July 22, 1587, and were forced to remain there, for the sailors refused to go to the Chesapeake, whither they had intended to remove the colony. Not a trace of the fifteen colonists who had been left the year before could be found. On August 18 White's daughter Eleanor, Mrs. Dare, presented her husband with a baby daughter, the first child of English parentage born in the New World. On August 20 the child was baptized Virginia Dare. White not long after returned to England for supplies for the colony, but when he came back the next year the company of over one hundred persons whom he had left behind had vanished, and all that could be discovered was the word "CROATAN" carved on a tree. From this it was inferred that they had gone away with Indians of that name, among whom in later years were found people of apparently mixed blood, bearing English names, who were thought to be descendants of the "lost colony."

Among those "lost" in the piny woods about Hatteras were White's daughter, Eleanor, her husband, Ananias, and their baby daughter, Virginia Dare. It must have been with a heavy heart that White, bereft of daughter and grandchild, again set sail to return to England.

There seems to be no doubt that the picture was painted by John White, the commander of Sir Walter Raleigh's third expedition to "Virginia" in the year 1587. It represents (in impressionistic style) the male Tiger Swallowtail, one of the common butterflies of the Carolinas, *Papilio turnus* Linn., the dimorphic female of which is *Papilio glaucus* Linn.

But there is another inscription on the original drawing in a different hand from that which we have been considering, and written with different ink. It is "*Mamank anois.*" What does it mean? I think it is the Indian name of the insect.[1] We can fancy White, "deft in the use of water-colors," receiving the butterfly from the hands of an Indian lad, seating himself with a scrap of paper, rapidly painting the picture and interrogating the boy for its name, which White scribbled upon the margin of his sketch.

But now another question arises. Who was the man who wrote the words: "*Hanc è Virginia Americana Candidus ad me Pictor detulit, 1587*"? Who was "me"?

A wood-cut of the original painting first appeared in that curious and now very rare old book: "Insectorum sive Minimorum Animalium Theatrum." The authorship of this book is exceedingly composite and a long time elapsed between its inception and its final publication. The subtitle of the book is as follows:

Olim ab
EDOARDO WOTTONO.
CONRADO GESNERO.
THOMAQUE PENNIO.
inchoatum:
Tandem
THO. MOVFETI *Londinati opera sumptibusq. maximis concinnatum, auctum, perfectum;*
Et ad vivum expressis Iconibus supra quingentis illustratum.[2]

[1] Since the writing of the above, Mr. M. W. Sterling, chief of the American Bureau of Ethnology, has kindly called my attention to the fact that in the Vocabulary contained in Strachey's "Historie of Travaile into Virginia Britannia, etc., 2," the expression "manaanggwas" is given as the Indian equivalent of the word *butterfly*. My suspicion is thus confirmed.

Below this comes the famous picture of the beehive, the trade-mark of the printer, Thomas Cotes, familiar to all Shakespearian students, for Thomas Cotes about this time was printing the second folio of Shakespeare, which has on its title-page the same beehive shown on the title-page of the work of which we are speaking, but not surrounded, as in the "Insectorum Theatrum," by figures of bugs, butterflies, spiders and millipedes. At the foot of the title-page are the words:

Londini ex Officina typographica
Thom. Cotes.
Et venales extant apud
Benjamin. Allen
in diverticulo, quod Anglice dicitur,
Popes-head Alley,
1634.[3]

Sir Edward Wotton stood high in the English diplomatic service. In 1586 he was sent to France to explain to Henri IV the intrigues of Mary, Queen of Scots, against Queen Elizabeth; and afterwards in 1610 he was ambassador extraordinary to France. He held many offices and died in 1626. He was deeply interested in entomology. Conrad Gesner died in December, 1565. He was for his day a great naturalist and the author of some of the earliest writings on natural history published in western Europe. He was a close friend of Dr. Thomas Penny. Penny was with Gesner on the continent when he died, and after his death helped to arrange Gesner's collections.

Penny was a physician of great repute and so was his friend Thomas Moffett, Mouffet or Muffet. Both had graduated at Cambridge; both had studied medicine on the continent; both were court physicians; both were botanists and entomologists. They collaborated for years. The interesting old book concerning which I am writing was begun by Penny and Gesner working together in Germany. Sir Edward Wotton lent a helping hand. When Dr. Penny died his friend and colleague, Moffet, took up the unfinished work, which he arranged and completed. In 1590 he dedicated it by royal permission to Queen Elizabeth and received official sanction to print it at The Hague. But delays followed. When James I of England came to the throne in 1603, Dr. Moffett changed the dedication to the king. At Moffett's death in 1604 the manuscript with its illustrations, pasted in where they were to appear, came into the hands of Darnell, Moffett's apothecary. Darnell sold the manuscript to Sir Theodore Turquat de Mayerne, Baron Albone, court physician in the time of Charles I. Baron Albone published the book at his own expense in 1634, dedicating it to Sir William Paddy, and in his dedication speaks of Moffett as "an eminent ornament of the Society of Physicians, a man of the more polite and solid learning, and renowned in most branches of science."

This in brief is the story of the book in which our picture first appeared on page 98, as a wood-cut, faithfully reproducing the original drawing. But who was the man who received the drawing from John White, and recorded the fact on its margin? It can not have been Gesner. He had died, as already stated, in 1565. I doubt that Dr. Moffett wrote the inscription upon the original drawing, for the handwriting is distinctly different from that of the body of the manuscript written by Moffett's pen. This leaves only two others of the joint authors to be considered. Dr. Penny

[2] *Translation*: Begun long ago by Edward Wotton, Conrad Gesner and Thomas Penny; finally prepared, enlarged and perfected by the labor and very great expense of Thomas Moufet, born in London, and illustrated by over five hundred figures drawn to life.

[3] *Translation:* From the printing office in London of Thom. Cotes, for sale by Benjamin. Allen in the lane which in English is called Popes Head Alley, 1634.

died in 1589. Sir Edward Wotton stood high at the English court. He was the friend of Sir Francis Drake and of Sir Walter Raleigh. He was very likely to have been brought into contact with John White, when the latter returned to report to Raleigh what he had done. I am not able to decide the question, but I am strongly inclined to think that the author of the inscription was Sir Edward Wotton, who gave it to Dr. Moffett, who pasted it into the manuscript where it to-day remains. Some student of chirography delving among the old papers in the British Museum may be able to settle the question. The original manuscript is preserved in the British Museum in the Sloane Collection (No. 4014). It carries both the dedication to Queen Elizabeth and to James I.

What is clear is that the first picture of an American butterfly was painted by John White, the leader of Sir Walter Raleigh's third expedition to Roanoke, in the year 1587, less than one hundred years after Columbus had made his first landfall in the New World, twenty years before Captain John Smith and his associates reached Virginia and thirty-three years before the Pilgrim fathers disembarked at Plymouth. The artist was the grandfather of the first white child of English parentage born on the continent of North America, Virginia Dare.

TWENTY-FIVE CENTURIES BEFORE CHARLES DARWIN

By TZE TUAN CHEN

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MANY books and articles have been written on Chinese superstitions and myths concerning the origin of life and living things, but, so far as the writer is aware, the deeper theories formulated by some ancient Chinese thinkers and the similarities between these theories and those held by Greek philosophers and scientists have been but lightly touched upon. This paper attempts to call attention to the fact that some ideas of the origin of the species, of variation, of adaptation and of the structure-function theory were formulated several thousand years before Darwinism came into existence and have all been neglected by Western writers in their history of the theory of organic evolution. It must be remembered that, however ambiguous these theories are, they were first expressed several thousand years ago.

One of the most curious aspects in the history of human thought so far as literature and science have revealed it to us is the strange interest taken in discussing the problem of evolution, which had two aspects: the origin of life and the origin of the forms of life. Ever since men were able to think it has been an open question as to the origin of things which they see around them. Even primitive people seem to have attempted to speculate on the causes of the origin of the universe and the evolution of life.

What is the alpha and omega of the universe? Whence came life? How did being become beings? Why have things been as they were? These are some of the eternal, metaphysical as well as scientific, problems which thinking men of all ages and of all countries, with all their limited information and all their intelligence and energy, within their brief spans of time, have endeavored to solve in one way or other as seemed satisfactory to them. Some have thought of all the wonders of life as the work of God; some ascribed it to the Logos; some named it the unknowable, while some others called it evolution.

While we credit the theory of evolution to modern Western thinkers, we are apt to forget the philosophers of the Orient who formulated almost the whole theory without knowing its significance. It is with this point in view that the writer will proceed to discuss in the following paragraphs this subject of evolution by indicating its position in Chinese myths and folk-lore and then attempt to give an account of some deeper theories as stated by some ancient Chinese philosophers.

EVOLUTION VIEWED THROUGH THE CHINESE FOLK-LORE AND MYTHS

There is a very popular myth in regard to the origin of life which is connected with the name of Pan-ku. He was considered the first living being on the earth, and he had the task, as the story goes, of chiseling and molding the world into its existing shape. He is pictured as a giant with a mallet and a chisel in his hands. It took him 18,000 years to complete his task. The work of Pan-ku was first devoted to the separation of the earth from heaven, and then to the giving of life to the earth which he had so industriously made. Hence he was the creator of our planet.

A second myth involves the name of Nu-ho-shih, supposed to be a goddess of great ability. She tried to make the

earth adaptable to living things, and her task was to patch the heaven which had been broken. Through long, hard work she succeeded in selecting and polishing certain stones by means of which the cracks of the broken heaven were patched.

In "Si-yu-chih," a very popular mythical story, we read about a queer stone which, exposed to the natural changes and tests and receiving some dynamic and vital elements from the sun, moon and stars, came to pass into life as a very intelligent monkey. Later, this monkey, owing to its superior intelligence and ability, was endowed with personality.

Another interesting myth explains that living things have their origin in a peculiar gas possessed by a powerful god. This god, having proved to be weaker than another god against whom he was warring, evolved a gas in which various fierce animals were present, and thus defeated his enemy. These freed, animals then came to live in the world.

Still another myth states that man was evolved from a broom. One day the broom was dropped from the heavenly paradise to the earth and there it remained for thousands of years. Becoming animated and possessing the abilities of walking and eating, it eventually became a man from whom men are descended. Some uneducated persons believe that men in ancient times did not die, but changed every hundred years by "molting."

Certain speculations are interesting. One country saying that life came with wind is based upon the idea that as wind swept over the earth it changed nonliving things into living beings. This reminds us of the speculation of ancient Anixemenes that air imparts life to all things.

Another bit of folk-lore bears some familiarity to the so-called planetesimal theory of Chamberlain. Country folk often say that living things first came to the earth from the moon. Their reason is based upon an assumption that the black spots they see in the moon are a monkey pounding rice, a snake winding its body around a pine tree, and so forth.

Some are fooled by inaccurate observations and superstitious traditions. They realize and recognize changes in things, but they give the wrong data. For instance, many still believe that a sparrow can change to a clam when it is dropped into the sea; that a shark will change to a tiger when it gets on land; that a fox possesses wonderful powers of transformation; that a rat can change to a bat; that fireflies come from cow-manure; that a wasp can make caterpillars his adopted sons and change their whole appearance; that a big snake can change to a dragon which later on will fly up to the sky. These traditional views, in spite of their fallacies, indicate the belief in change from one type of animal to another type.

So much for mythological stories. Let us now proceed to investigate what the ancient thinkers have said about evolution.

Origin of Life

In regard to the origin of life, Lao-tze (born 604 B. C.) tended to explain it philosophically. He said, "Everything comes from something, something comes from nothing." This assertion bears some familiarity to the theory of Squarez, who believed that the *materia prima* was made out of nothing.

Some philosophers had the idea that in the beginning of the world there existed five "elements": gold, wood, water, fire and soil. Through the positive and negative action of these "elements" life was before long formed. Similar to this is the theory of Empedocles and Anaximander who believed that life had its origin in the interaction of the four

"elements": fire, water, air and earth. Anaxagoras believed that all animals were generated out of three elements: water, fire and earth. Thales thought that the ocean was the parent of all things.

Other philosophers explained the origin of life in the presence on the earth of a duality of forces called "Yin-Yang." "Yin" gave life to females and "Yan" to males. In these females and males all living things have their origin.

As regards the cause of the origin of life, ancient Chinese thinkers have only ambiguous answers. Like modern evolutionists, Chuan-tze (born 330 B. C.) and Lao-tze formulated their theories which had nothing to do with God. Lieh-tze said, "Various forms of things are seen, yet how they could come is very hard to know, that we could not find the maker who shapes them." Chuan-tze, having a similar idea, expressed it by saying of a shadow, "A shadow says to itself: 'Am I present because of still some other thing?'"—and further, "Could a thing rise before another thing inasmuch as when a thing is already included in things it could not go before them?"—and further, "Ten thousand changes go on, and no one knows where they will end or when they have begun." Ordinarily we think in terms of cause and effect, and we try to trace the sequence of cause to the first cause. We may get still beyond this and ask what the cause of the first cause was. We think of one cause before another infinitely and beyond our reasoning. In fact, the question is this, "Is there a first cause?" and it remains unanswered. Chinese philosophers long ago pointed out the fact that we should not ask for the cause of the first cause because there could be no cause preceding the first cause; otherwise it would not have been called the first cause.

Origin of Forms of Life

How have the various forms of life come into existence? Two conflicting hypotheses have been presented: special creation and evolution. According to the first supposition, species were separately created and definitely fixed types of life, whereas by evolution we mean the continuous developing of things from the homogeneous to the heterogeneous, from the simple to the complex. Theories formulated by the ancient Chinese belong to the latter hypothesis.

Dating back as early as the sixth century B. C., Confucius in his "Yi-ching" tried to show that complexity was derived from a simple source. The "Yi-ching" also expresses the idea that things were originated from a single simple source through "gradual unfolding and branching." According to the ancients, the alpha of the universe is simplicity, which changes, evolutes and multiplies into this complex, compound, manifold world. The Taoist's *Tao* and Confucius's *Yi* are almost identical. The truth is that the world changes from the homogeneous to the heterogeneous; some call the process Tao, others call it Yi, while we call it evolution.

The process of evolution as conceived by the ancients is a continuous development. The following passage from the "Yi-ching" appendix illustrates this idea very well: "Following the existence of heaven and earth, there is the existence of all things, there is the distinction of sex. . . ." This is the principle of continuity. Man is an object of nature and product of evolution and, as well as ants and bees, is but a transitional state in the natural evolution from lower to higher types.

Here are more stimulating paragraphs from Chuan-tze and Lieh-tze (fourth century B. C.). Chuan-tze's theory is the theory of *self-transformation,* which probably meant a gradual process of

evolution. He said, "The life of all living things is like the running of a horse, changing and moving at every moment. What do living things do? And what do they not do? They will naturally transform themselves." He furthermore definitely said, "All living things are species developing to various forms through the process of variation." He meant that everything is derived from some source, and by gradual changes they have become things of unlike forms. The dissimilarity does not appear at once; this is the result of progression, of development through generations of time. Here he states clearly the idea of variation, wherein lies the idea of origin of species.

Chuan-tze also understood adaptations, although he did not point out clearly that adaptation was responsible for the transformation of life. Chuan-tze stated: "When a man sleeps in a damp and moist place he will get sick and may die, but does this affect a fish? When a man dwells on a tree, he fears falling, but is it so with a monkey? Which of these is the right situation? Man eats vegetables; a deer eats grass, and a crow feeds on dead rats. Which of these is the right food?"

In another place he continued: "A horse can run a thousand *li* in one day, yet it can not catch one mouse like a cat, because they are different in traits. An owl can see an insect or the small tip of a twig at night, but can not see a mountain in the daytime, because it is different in structure from other animals." Here, then, is another important theory stating that with the structure goes the function.

Hui-nan-tze said: "Duckweed lays its roots in water, but the woody plant lays its roots in soil. Birds move in the air and animals move on solid things." Here are further expositions of the idea of adaptation.

How the changes take place, however, was not explained by these philosophers. Chuan-tze, Lieh-tze and Confucius had the conception of *Tao*. By *Tao*, Confucius meant change. The following quotation from Confucius will make this clear. "The heaven says nothing, but the four seasons run their course and all things are produced." To Lao-tze, *Tao* likewise meant "spontaneous life in the universe."

This is but a brief account of the ideas of evolution appearing among the speculations of ancient Chinese thinkers. While the Chinese anticipated many theories, collected a great variety of facts, invented some valuable propositions and brought a few to a high degree of philosophic significance, yet they have never pursued a single subject in a way calculated to lead them to final success. The variation, the adaptation and the structure-function theory—all were hinted at, but there were no results until centuries later when our western science stepped in and secured the prize.

SOME UNIVERSAL PRINCIPLES OF COMMUNICATION

By JOHN MILLS

BELL TELEPHONE LABORATORIES

ALL communication involves conventions and understandings as to the meanings of symbols, and it is usually through making symbols audible or visual that intelligence is transferred. When the distance is too great for unaided ear or eye, electrical systems apply. All those in use to-day derive fundamentally from the telegraphy of Morse and the telephony of Bell. Telegraphy and telephony, by open-wire lines, by cable, submarine and aerial, or by radio, however unrelated in origin, early development and commercial exploitation, are now more than sister arts—physically they constitute a unitary system based on common principles.

For Morse and Bell, working in the early days of modern science, batteries were the convenient sources of electrical currents although electromagnetic induction as discovered by Faraday was being applied to the development of generators. The motor action of a current was also known and was being rapidly applied. A simple motor action of which both inventors made effective use was the attraction by a current-carrying coil for an iron armature.

There were thus at their hands, although in rudimentary form, some of the essential elements of a communication system. It remained for the inventors to develop the still more essential concept of such a system and to supply the remaining elements. Time has refined their elements, conceived more basically, developed or adapted new principles and mechanisms; but, broadly speaking, their elements are typically those necessary to any system of communication. First, there must be a source of energy which can give rise to an electrical current; second, a mechanism for varying this current in conformity with the speech or signal which is to be transmitted; third, a medium for this transmission, and last, a mechanism which will translate the current variation into speech or signal. For Bell the second element was the telephone transmitter; for Morse, the telegraph key. For both the fourth element was an electromagnetic motor, in one case the lever which clacks in a telegraph sounder and in the other the diaphragm which vibrates like a drum head.

In the telegraph system the lever of the sounder reproduced the up-and-down movements imposed by an operator upon the lever of the key at the sending end of the line. The time between up-and-down movements was the basis of the code of signals. Relatively long intervals represented dashes, and shorter ones, dots. The receiving operator was enabled to perceive the interval aurally because the lever made characteristically different sounds when it struck against the upper and the lower stops. Visually sometimes the series of dots and dashes was recorded by arranging the down movement to bring a pen against a moving strip of paper.

In the telephone system, back-and-forth movements of a diaphragm, as occasioned by the sound-waves in the surrounding air, were reproduced in movements of the diaphragm of the receiver, and these established sound-waves intelligibly similar to the original. The code for the interpretation of these sounds was already adopted in the language conventions of the speaker.

By word or sign, therefore, but fundamentally by movement, is electrical com-

munication accomplished. The signs may lead, and soon did, to complete words, recognizable by the conventions for printed letters. By proper arrangements of the motions at the receiving station letters are printed on a moving strip of paper by an electrically operated typewriter. For this purpose the telegraph key at the sending station is replaced by equipment which includes a typewriter keyboard. The entire assemblage, then, becomes the so-called "printing telegraph." By other arrangements for the reproduction of movements, as in the telautograph, handwriting has been transmitted. And finally, by more elaborate and refined sequences of movements, images may be transmitted: picture transmission is a commercially available service, and television pauses at the threshold, a practical accomplishment of undetermined economic possibility.

These later systems involve the conscious and deliberate control of electrons. Such conscious control of electrons in communication systems dates from the development of the three-electrode high-vacuum thermionic tube. The tube was applied to long-distance telephony in the 1914 opening of Bell System service between New York and San Francisco and in the 1915 experimental transmission from Washington to Paris—the beginning of a development which has already linked to the American telephone system those of most of Europe.

In wire transmission the vacuum-tube became a circuit element; along the transcontinental line, for example, it was interposed at Pittsburgh, Chicago, Omaha, and so on, to amplify successively, as they became too much attenuated, the complex but feeble currents of telephony.

In radio transmission the tube was utilized in the terminal equipment. At the sending station it gave rise as a generator to the high-frequency radio current, varied and modulated this in conformity with the current from a telephone line or transmitter and then amplified the resultant current, with its hidden speech significance, millions of times to impress it upon the transmitting antenna. At the receiving station other vacuum-tubes reversed the process of modulation, that is, detected in the antenna current the modulating cause and obtained a current similar to that in the original transmitter which they then amplified and sent on its way to the distant telephone receiver.

Long before commercial radio-telephone service with the European continent was initiated—since its development, requiring among other things studies of an unmapped transmission medium, was interrupted by the war—the principles of operation just described had been applied in so-called carrier systems of telephony and telegraphy to the more efficient use of the long-distance open-wire network of the Bell System in the United States. Where a single pair of copper wires had previously transmitted at any instant only a single conversation, properly designed terminal equipment, employing vacuum-tubes, permitted as many as four simultaneous conversations. Each conversation had its speech significance carried by a distinctive current—a current of frequency different from those assigned to the other conversations. Multiplex telegraphy followed the same principle, using distinctive currents for each telegraphic channel.

The vacuum-tube also has its part in the system for the transmission of photographs, which was well established on the telephone lines of this country by 1925, and has a part in the recently demonstrated systems for television. In both these more recent developments, however, another electronic element—the photoelectric cell or electrical eye—

plays the leading rôle in the terminal apparatus. This cell is a light-sensitive device which gives rise to an electric current always accurately proportional to the amount of light which falls upon it. In television, still another device, utilizing known actions of electrons, plays the counterpart to the photoelectric cell. This is the neon tube, an electric lamp keenly sensitive to variations in its electrical supply.

All these systems of communication, wire and radio, whether for telegraphic signals or spoken word, or for a scene—all these systems operate on certain common physical principles. With them there might be included the systems for sound pictures, of which two developed in Bell Telephone Laboratories are in wide use to-day. These, also, are telephonic systems, but in them transmission is divided into two steps by an intervening act of recording. In one system the record is cut by an electromagnetic graver on a wax disc; in the other it is photographically recorded on a strip of film as a series of striations of varying photographic density. In the disc system reproduction comes through a special form of telephone transmitter actuated by a needle which follows the groove in the phonograph disc. In the case of the film an electrical eye observes from instant to instant the varying photographic density of the sound record and gives rise to a corresponding current.

Any communication system to-day involves apparatus for two distinct purposes: the first is the production of a channel for communication with its related terminal equipment; the second is the control, switching and supervision of the channel.

In complexity and first cost the apparatus required for the second purpose may exceed that for communication proper. This is particularly true in the short-distance communications of large metropolitan areas where improvements in reliability, speed and facility of service are obtained by bewildering assemblies of apparatus in the huge central officers. In the panel-type dial system, for example, there are complicated assemblies of small electromagnetic devices, intricately interconnected, each of which serves in lieu of an operator and constitutes an electrical brain of the system. Each assembly receives from a subscriber's dialing operations the same statement of desired numbers as would an operator, storing the information within itself. It then proceeds as would the operator, consulting a routing guide, to handle the call until the distant party answers or until it reports back that he fails to do so.

Within these decoder senders, as they are called, hundreds of operations are performed successively for every call of a subscriber to which they attend. They must do their appointed tasks accurately; and, because they are complicated and expensive, should they fail they must be promptly inspected and readjusted. In their more recently designed forms, therefore, new cerebral functions are being provided. Should one of these senders in its sequence of operations fail at any point it will, of its own action, disconnect itself from the line of the subscriber whom it is answering and report to a maintenance man. Even more, for his information it will print on an electric typewriter the number of the operation at which it failed. Could more human intelligence and efficiency be demanded of any organism than that it should quit work when diminished powers endanger its further acts, call for help and accurately diagnose its own complaint?

Of the apparatus in a communication system concerned primarily with transmission there are to be distinguished three groups: namely, transmitter, medium or channel for transmission and

receiver. The terminal equipment is fundamentally apparatus for energy conversion, and receiver and transmitter usually perform complementary operations. In telephony the transmitter is a sound-sensitive device actuated by the mechanical energy of sound-waves and giving forth electrical energy. The receiver is a sound-active device, converting electrical energy into mechanical energy. In ordinary telegraphy the transmitter involves a key whose up-and-down motions at the hand of the operator are reproduced by the bar of the telegraph sounder at the receiving station. In picture transmission a light-sensitive cell receives varying illumination depending upon the photographic density of the negative which it is scanning; and at the receiving station a source of light and an electromagnetically controlled shutter serves as a complementary light-active device. In television a tube of neon gas, which responds to the current impulses from the light-sensitive cell of the distant transmitting apparatus, is the complementary light-active device.

In principle it makes no essential difference whether the transmitter acts to convert mechanical into electrical energy or acts to control a source of electrical energy. Of the first type was the original telephone transmitter of Bell, which converted the vocal energy of the speaker. Incidentally the same device also functioned as a receiver performing the complementary conversion. The transmitter, however, with which Bell sent the first complete sentence, like most of those employed to-day, was a device for controlling the current from a battery. Its energy output depended then not upon the vocal power of the speaker alone but primarily upon its efficiency as a controlling mechanism. In telegraphy, in the same way, the energy output of the sending key does not depend upon the operator but upon the battery which the key controls; and at a receiving station the energy of the received current is not directly converted into sound but serves to control another battery which supplies energy to the sounder.

In general words, therefore, a transmitter operates to control, that is to modulate, the current from an energy source in conformity with the signal to be transmitted. It makes no difference whether the current which is modulated is otherwise unvarying or not. An alternating current would serve provided that it did not have a periodicity, that is a frequency, which would be confused with that of the signal itself. Both Morse and Bell, working in the early days of the electrical arts, employed batteries, which were the energy sources then available, and so used unvarying currents, that is currents of "zero frequency," as we would say to-day to preserve the generality.

Those who followed Hertz into radio used the highly damped and alternating discharges of condensers through inductive circuits and thus employed groups of high-frequency waves. For telegraphic purposes these proved entirely practical since the high frequency was efficiently transmitted from their antennas, and the group frequency, being greater than the frequencies involved in the dot and dash signals of their code, gave rise to no confusion. When, however, they came to attempt radiotelephony, among their many difficulties was the fact that their currents involved frequencies which confused the listener, being in the frequency range that should have belonged solely to the voice-modulated currents.

The difficulty was to be overcome by the adoption of a generator of so-called continuous waves. In the 1915 transatlantic experiments, a vacuum-tube acted to convert energy from direct-current sources into a high-frequency. The current had a definite and single

frequency determined by the capacity and inductance which were associated with the tube. This current was then modulated by the speech current from a transmitter, amplified and impressed upon the antenna. The modulated current was highly complex, including as components the carrier current itself and the products of modulation; but the important thing about it was that its component of carrier current was of a single frequency. The carrier currents which had been utilized in the early attempts at radio-telephony had not been of single frequency but complex currents involving components of a wide range of frequency; and corresponding to each of these components there had been products of modulation, giving rise to confusion much confounded.

The nature of the confusion appears from a consideration of the act of modulation of a single-frequency current by a transmitter current itself involving only a single frequency. A tuning-fork produces essentially a single-frequency note. Imagine its sound to actuate a transmitter and the resulting current to modulate a carrier current. For convenience of arithmetic assume the carrier frequency to be 100,000 cycles per second and the fork frequency 1,000. The current from the modulating device, which is again the versatile vacuum-tube, will have three high-frequency components, one of the frequency of the carrier and the others so-called sidebands. These are respectively above and below the carrier frequency by the amount of the modulating frequency, and so are $100{,}000 + 1{,}000$ or 101,000, and $100{,}000 - 1{,}000$ or 99,000.

If, however, a complex sound, involving notes of several different frequencies, actuates the transmitter each note will produce its sidebands. The intensities of the currents in each pair of sidebands will depend upon, and be directly proportional to, the intensity of the component note which produces them. Music or speech may thus be hidden in sidebands of modulated current and transmitted as high-frequency currents.

At the receiving station another vacuum-tube acts to produce currents whose frequencies are sums and differences of those impressed upon it. If the currents of the previous arithmetical example are received the difference terms will be currents of frequency 1,000, that is, of the original modulating frequency. These are easily distinguished from the high-frequency currents, and when passed to a telephone receiver they produce the same sound as if they had been directly transmitted to it and none of the intervening operations had been performed.

The modulated currents and their accompanying carrier current form a group relatively easily separated from any other similar group if the frequency bands of the group do not overlap and are not too closely adjacent. The allowable closeness depends upon the sharpness of discrimination of the selective circuits which are used for that purpose; and that again depends to some extent not only upon the engineering skill of their designers but also upon the economically allowable complexity and cost of the circuits. In present-day radio broadcasting the carrier currents which are utilized by the stations in any particular area are legally separated by 10,000 cycles. The allowable separation of carriers, however, in order that one radio station's output shall not interfere with that of another through being simultaneously received and at too nearly the same loudness, depends upon the range of frequencies which the sidebands must involve in order that they shall contain the essential notes in the speech or music of the program.

What range of notes is essential for reproduced speech depends upon the occasion. For intelligibility a compara-

tively small range is required; naturalness demands more; and for essentially complete illusion, such as sound pictures require, still wider range is needed. For a telephone conversation, where a voice is to be recognized and its nuances of inflection appreciated, the range from 100 to 3,000 cycles will serve; but the range from 60 to 7,000 is none too large for an esthetic illusion from a "talkie." Music, particularly of stringed instruments, requires a wider range than speech, but very good effects can be obtained with only a slightly larger range when it is unaccompanied by pictures.

For signals other than those of music and speech, the necessary range of frequencies which must be allowed to the sidebands depends upon the character of the signal and the speed of signaling. In telegraphy, for example, if a dot occupies half a second and is separated from the succeeding signal by an equal interval of time, obviously a frequency of one cycle per second must be allowed. But this frequency is insufficient for good definition of the received signal because the abrupt change of current from zero to its full value and back to zero, as occasioned by the telegraph key, is not equivalent to an alternating current of a single frequency. Instead it is equivalent to a complex alternating current involving a whole series of frequencies, three, five, seven, and so on, times the frequency which at first glance one would assign to the dot. Essentially complete simulation is obtained if frequencies as high as eleven times are transmitted and received.

Whatever the maximum number of dot signals which the telegrapher wishes to be able to transmit per second, allowance must be made, therefore, for a sideband with a frequency range eleven or so times as large. As a rule, a band of one hundred cycles does very well for the ordinary speed of telegraph signals. Speech and music, as earlier figures showed, require more, but television imposes the most severe requirement.

In any television system which can be imagined, some mechanism must send electrically information about the relative light and shade of successive elementary areas in the scene which is to be "televised," as the newspapers would say. This information must be applied at the receiving station to the reconstruction of similarly arranged elementary areas of light, differing in intensity according to the information transmitted. Furthermore, the complete scene must be reconstructed in a time within the limit of the persistence of vision of the human eye, that is, under one sixteenth, perhaps only one twentieth, of a second.

Imagine, as may well occur, that one elementary area of the scene is bright (when current must flow) and the next adjacent practically dark (when there would be no current to be transmitted). The condition corresponds exactly with the sending of a dot in telegraphy. If the scene is analyzed into 10,000 elementary areas—and this would correspond to the detail in one square inch of 100-mesh halftone—there would need to be the possibility of transmission of 5,000 dots for each time the scene is reproduced, or approximately twenty times as many dots per second. That means a width requirement for the sideband of 20 times 5,000, or 100,000 cycles per second. Such a requirement is equivalent to that of approximately one thousand telegraph channels or thirty (commercial) telephone channels or ten adjacent channels for radio broadcasting. Therein lies a specific economic limitation for the future of television.

In fact, there is a general limitation for all forms of communication. Given a communication channel effective for transmitting a definite range of frequencies and given a type of signal to

be transmitted, simple arithmetic permits a determination of the speed at which the signal can be transmitted; or, what amounts to the same thing, if the frequency requirement of the signal is less than that which the channel will permit, then the number of signals which can be simultaneously transmitted may be determined. An interesting illustration of this principle was given by R. V. L. Hartley, who first stated it.

In substance he said, let us imagine a line capable of transmitting all frequencies from zero to 3,000 cycles. This would be sufficient for a good telephone conversation. We now imagine the current from the speaker's transmitter to be recorded, as on a phonograph record. We then turn this record for reproduction at twice its recording speed, reproducing from it electromagnetically and transmitting over the line to the distant station. For the transmission of the speech we use the line but half the normal time. At the other end we again record it but now at double the normal speed of the turntable. We then reproduce for the listener at half that speed, that is, at just the speed of the original record of the distant speaker. At first thought it would appear that we could do the same for another pair of speaker and listener and utilize the remaining free time of the line for that speech and thus obtain a double efficiency for our line.

The fallacy resides in the fact that neither speech would be adequately transmitted. Reproducing with the turntable run at twice normal speed would mean that any frequency originally recorded would be doubled; a sound of 1,500 cycles would become one of 3,000. Since the line, by assumption, will transmit no frequencies above 3,000 no sounds with original frequencies above 1,500 cycles will be transmitted. In effect, therefore, half the frequency range of the message would fail to get through, due to our hurry. Similarly, of the other message what might be called a half would get through; and we would obtain halves of two different messages instead of both halves of one. There would be no gain, and in fact a loss since neither message would have its desired intelligibility.

Halving the time utilized in transmission always requires doubling the range of frequencies which the channel must transmit. We can't gain by beating the devil around the stump, and in practice the communication engineer doesn't try. In practice it works out that the effort is confined to using to its fullest the transmission range of each medium, to placing the sidebands of various signals as close together as possible and to avoiding the transmission of any unnecessary bands of frequency.

Two illustrations show the practice. Wire lines in the Bell System are multiplexed for transmission between stations over distances long enough so that savings due to more efficient use of channel are greater than expenses due to added terminal apparatus and operation. Telegraph messages, for example, because they require a frequency range from zero to about 100 cycles per second, are sent over the same pair of wires as telephone messages which require from about 100 to about 3,000 cycles. In other cases some ten telegraph messages, with their bands adequately separated, are sent over the normal pair of telephone conductors. Sometimes by suitable terminal equipment there are transmitted over the same pair of wires not only the telegraph message and normal telephone message which together occupy about 3,000 cycles but also a second telephone message, occupying a similar range but carried by a high-frequency current and utilizing the transmission capacity of the line for frequencies as high as 10,000 cycles. In still another instance the lines are specially condi-

tioned, and a frequency range is made available from zero to about 28,000 cycles. Over such lines, by suitable terminal equipment, there may be sent in addition to the ordinary telegraph message and telephone message a total of three more telephone messages. In such cases, however, each of these additional messages is divided into outgoing and incoming portions and a frequency range of 3,000 or so cycles assigned to each portion. The various messages, therefore, use about twenty-one of the available twenty-eight thousand cycle range, the remainder being lost in providing adequate separation between the bands of the various messages.

The other illustration is found in the long-wave transmission system which provides radio-telephony with Europe. There new methods have resulted not only in increased efficiency in use of the available frequency range but at the same time in economies of operating power. Instead of transmitting the carrier frequency and both sidebands which result from its modulation by speech currents, only one sideband is transmitted. For purposes of reception a current of the carrier frequency is locally introduced at each receiving station and hence demodulation proceeds practically in the normal manner. In addition, by properly disposing the transmitting and receiving antennas in America and in Great Britain and by special equipment it is possible to use the same frequency of carrier for both outgoing and incoming parts of the telephone conversation. There is thus withdrawn for transatlantic telephony from the general ether channel the narrowest band possible for telephony, namely, that corresponding to the frequencies essential to the intelligible and natural reproduction of the human voice.

SYNTHETIC SEAS

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SUPPOSE that all the water in the world were to be destroyed. Do you think we have enough scientific knowledge and practical ability to make a substitute for it?

If we can make any liquid at all, we ought to be able to produce one to replace as simple a compound as water. And, because the loss of water would be a great blow to everybody, we could get all the world to concentrate on replacing it. With this initial confidence, let us see what are some of the conditions that would have to be complied with.

Right within our own bodies and within the bodies of other living creatures our new liquid would have to perform many functions. Water is far more vital to us than food. People can live a long time without food, but it is an exceptional person who could exist more than three days without water. About 75 per cent. of our bodies is water, and if a person were to lose 20 per cent. of the water content of his body he would die. The blood, which itself is mostly water, distributes food to the cells as well as oxygen to burn the food. It returns bearing the ashes of the body fires. And, strange to say, one of those ashes even is water, because the hydrogen in the food burns to water. Thus water is actually manufactured in the body—about a pint of it every day. The liquid we are going to make will have to perform every one of these necessary functions, and the process by which it is manufactured must be one that can be carried on right within the body itself.

Because people must be able to drink our substitute for water, it must have no taste, and no odor. It must also be able to purify itself from harmful bacteria simply by flowing in air and sunshine. Otherwise it would soon become unfit for drinking.

Our liquid must be suitable for performing another remarkable function in the system, which water does in an ideal way. It must regulate the body temperature. Whenever the body gets too warm, water is forced out through the pores of the skin, and evaporating there carries heat away from the body. Dr. Slosson has said that water is twice blessed. It bestows a blessing as it comes and as it goes—especially as it goes. We appreciate the coolness of a cold glass of water, but it is many times as cooling later on as it issues and evaporates from a million pores. Even a cup of hot tea cools one off, because as it vaporizes from the skin it carries away with it fifty times as much heat as was taken into the body with the hot tea.

Our substitute for water will have to be able to play an important rôle in the lives of plants, too. It will first have to keep the ground soft enough for tiny roots and sprouts of plants to penetrate. It must be capable of being absorbed out of the soil by the plant roots, and of coursing up through the plant, bearing along with it a load of mineral matter dissolved out of the soil. Then, under the influence of sunlight and the green coloring matter of the leaves, some of our substitute for water must unite with carbon dioxide to build up the tissues of the plant, and the remainder of it must pass out through the pores of the leaves and evaporate off into the surrounding air. Later on, it will have to fall again as rain and cleanse the plant from accumulated dust, and then sink into the

soil, only to pass up through the plant again, and so on and on in an infinite cycle.

Our new liquid will have to fill the needs of the kitchen, also. There it must be used for washing things: food, dishes, tables, floors, windows, everything. But its most important use will be to cook with. And, if our liquid is to be used for cooking, it will have to boil at a temperature that is suitable for cooking. Thus, it would be a big nuisance to the cook if our substitute for water were to boil at too low a temperature, for then no cooking could be done except in pressure vessels. The same liquid that is used in the kitchen for washing and for cooking must also be used as one of the principal ingredients of many of the foods prepared there. In fact, we eat no food that does not have water either added to it or already present in it. There is water in soups, in vegetables, in meats, in salads and even in bread and in cakes.

Another fortunate characteristic of water that our liquid will have to have is that it does not boil away very fast. A kettle of water over a hot fire boils and boils and boils for an hour or more, and still there is plenty of it left. Even after a vessel of water has been heated up to the boiling point, it takes seven times as much heat to convert it from a liquid to a vapor as it did to warm it from 70 degrees up to its boiling temperature. The heat required to boil off a gallon of water is nearly ten times as great as for some other liquids. It is this fortunately high latent heat of water that keeps it from boiling away so fast, and that makes it evaporate out of rivers and seas so slowly.

Ice or frozen water is used in the kitchen also for cooling. It cools the refrigerator, and it chills drinks and salads. Melting ice, with its high heat of fusion, makes a little section of the Arctic Circle pass right through the kitchen. And besides, it is water in the steam radiator that heats the kitchen in winter. So, if our liquid is to replace water in the kitchen, it must be suitable both for heating things and for cooling them.

Another important requirement that our new liquid will have to meet is that its vapor must be lighter than air, just as is the case with water. If water vapor were heavier than air, then there would be no clouds and no rain. When the vapor of water mixes with the air just above the surface of the earth it makes the lower layer of the atmosphere lighter than the drier air above. And so the heavier atmosphere above settles down toward the earth, and the lighter water-laden air rises into the higher atmosphere. It is cold up there, and the water vapor is condensed to visible droplets that we call clouds, from which the earth gets the rain that purifies and cools the air, cleanses vegetation and makes all life possible.

But suppose water vapor were heavier than air. Then there would probably never be any rain, because the heavy water-laden atmosphere would stay near the surface of the earth. Not only this, but we should often be living in a dense fog as bad as those in foggy London, which the Londoner sometimes compares to pea soup. So this matter of density of its vapor, also, must be taken into account when we make our liquid, for a chain is no stronger than its weakest link.

And here it should be said that there is a conflict between the essential qualities of lightness of vapor and correctness of boiling point. For a compound whose vapor is lighter than air, the boiling point of water is quite abnormal. If water as a liquid possessed the same physical constitution, or if it existed as a liquid in the same state of molecular aggregation as it does as a vapor, its boiling point would be around 212 de-

grees *below* zero, instead of 212 degrees *above* zero as it happens to be. So here we must make a compound whose vapor is lighter than air, but whose boiling point is more than 400 degrees higher than such a compound normally would have. In order to do this we will have to find a compound whose molecular weight decreases as it changes from the liquid to the vapor state.

And then, too, the vapor of water in the air has a tremendous influence upon climate. Water vapor in the atmosphere acts a little like a wool blanket wrapped around the world. It lets the bright heat rays from the sun filter in to warm the ground, but it stops the dark heat rays reflected back from the ground, and prevents them from radiating away and being lost. If it were not for water vapor in the air we should not have the pleasant climate that we have become accustomed to. Instead, the temperature would probably be much like that which prevailed here during the prehistoric ice age. The compound we are to make will have to be able to influence our climate just as water does, of course.

Another thing about water that we must not lose sight of is its usefulness as a means of transportation. Man has swum in it and navigated it by means of logs, canoes, boats and ships since the earliest times. And water is suited to that purpose in an admirable way. It is dense enough to buoy up heavy objects, and at the same time it is mobile enough to flow with great freedom. Suppose water were as light as gasoline. Then men or animals could not swim. Even wood would sink. Boats would not be so useful, because they could not carry such large loads. A wreck at sea would be a much more terrible thing than it is now, for everybody on board would sink like stones. To fall into the water would mean almost certain death. Even fish would need to be much lighter than they are.

Speaking of fish, if it were not for the fortunate fact that water dissolves air in considerable amounts there would be no fish as we know them, for even fish must have air. But, because water does dissolve life-sustaining air, the population of the waters of the world is much larger than that of the land. Life must be possible both on and within the liquid we are going to make.

There is also another unusual property that must be put into our substitute for water. When frozen into ice it must be lighter than when in the liquid form. If ice were heavier than water, it would sink to the bottom as fast as formed and settle there, a frozen mass. It would not melt in summer, either, because the water above the ice is such a poor conductor of heat that little of the warmth of summer would ever penetrate down to it in its protected bed at the bottom of river, lake or sea. With each succeeding winter our lakes, our rivers and even our seas themselves would gradually accumulate ice at their bottoms, until finally they would be just one solid mass of ice.

We will have to make some very special provisions to get incorporated into our new liquid this quality of being lighter after it is frozen than before, because that is not a usual property of matter at all. Nearly all liquids contract when they freeze, and so get heavier instead of lighter as they pass over from the liquid to the solid state. And even water contracts as it cools until it reaches a temperature just a little above freezing. But there it reverses its behavior completely and begins to *expand* as it is cooled still further. The effect is that after water has been frozen to ice it occupies a larger volume than the same weight of the liquid. The reason why ice floats on water is that water has a fortunate property that is not common to other things in nature.

Another valuable thing about frozen water that we will have to make sure to incorporate into our liquid is that it always forms very slowly, even on extremely cold nights. As water freezes, the process of freezing is greatly retarded by the heat given off during the freezing process. The amount of heat liberated during the freezing of water is so large that it actually takes four times as much cold to make a pound of ice out of a pint of water at its freezing point as it takes to cool the pint of water down from 70 degrees to its freezing point. This large heat-evolving property of water as it freezes has a tremendous influence in slowing up the formation of ice and in keeping bodies of water from freezing solid in winter. The heat given off by freezing water actually helps to moderate the temperature of cold nights, strange as that may seem.

Still another one of the essential uses of water that we will have to incorporate into our new liquid is as a medium for developing power. Water that has been drawn up into the clouds by the energy of sunshine and then poured down on the high-lands as rain is employed directly to turn the wheels of industry as it hurries back down to the sea. And then steam is made to do useful work for mankind. One quart of water makes 1,700 quarts of live steam. By means of the steam engine, this immense expansive force of water has been made to change the whole economic system of the world, greatly enlarging the scope of people's activities.

Coal is ordinarily thought of as being the most essential thing around a steam power plant. But that is not true, at least with respect to the amount of it that is used. For each ton of coal fired in an up-to-date power plant, from 500 to 1,000 tons of water are required. The reason for using more water than coal in the steam power plant is that water is employed there both for generating pressure and for reducing pressure, paradox though that may seem. The effective push given to the pistons of the steam engine depends upon the difference between the pressures at the inlets to and at the outlets from the steam cylinders. This differential is made as large as possible by introducing water to the cylinders in the form of live steam under high pressure, and then condensing the steam back to liquid water as it leaves the exhaust. The result is that on the exhaust side the pressure is actually reduced to a minus value, or to a vacuum, thereby making the greatest possible differential between the port where the high-pressure steam rushes into the engine and the point where it later leaves the system as liquid water at almost no pressure at all. It is water, of course, that is used for reducing pressure by cooling and condensing the exhaust steam.

Our substitute for water must be good for putting out fires, and for cooling the fever of the sick. It must not be too light, nor yet must it be so heavy as to float away the stones and the soil like pieces of wood. In winter it must not rush out of the sky in large nuggets like hail, but it must come down in gentle flakes and spread a warm blanket over the freezing world. It must not be capable of being burnt up or destroyed in some unsuspected way. It must be able to go through many changes and many conditions, and still retain its original composition and characteristics. The supply of it must not diminish with time. All these essential properties water has. Every hydrogen-containing compound that burns raises the water supply of the world. Every automobile engine manufactures water. Water vapor pours from the smoke stack of every power house and from the chimney of every home. The American automobile alone increases the amount of water in the world by 250 million barrels a

year—as much as is used by a city of 300,000 people. As the world's supply of combustibles is going down, its reserve of water, that life-giving and most useful liquid which we will have to replace in some way, is going up.

In spite of all its perfectly amazing qualities, water, as we have known it so intimately and so long, is composed of just two common gases—hydrogen and oxygen. If 1,244 volumes of hydrogen gas are mixed with 622 volumes of oxygen gas, if the little individual particles are caused to combine and then if the vessel is cooled off afterwards, there is obtained one volume of liquid water. To squeeze those 1,866 volumes of the mixed gases down to the one volume that the desired product occupies would take a pressure of 25,000 pounds on each square inch of surface. To hold together just one pint of water, the equivalent of over a million pounds pressure has to be supplied.

But, of course, we can not hold our new compound together with a push from the outside. We will have to utilize a pull from the inside to tie the components together, as is the case with water, and it will have to be a very strong pull too. This means that in selecting the components of our new liquid we are limited to those that have a natural affinity for each other.

And, another thing, where in the world will we get enough basic material to make our new supply of liquid out of? Can we find large enough amounts of a pair of gases similar to hydrogen and oxygen that may serve the purpose? One of the easiest ways to get the answer to this question of source, perhaps, is to find out how much hydrogen and oxygen had to combine forces to make the world's present supply of water. By far the most plentiful gas that is known now is air. A measure of the amount of air there is may be had from the fact that the shell of air around the earth weighs enough to press down on each square inch of surface exposed at sea level with a force of about fifteen pounds.

But, if all the hydrogen and oxygen that make up the water in the world were to be let loose above the earth, the pressure, instead of being fifteen pounds on each square inch, as at present, would be 400 times as great, or 6,000 pounds. Since air is the most plentiful gas we have now, it is quite evident that we can not find 400 times as much of any other gases, which is the huge amount that would be needed to produce a substitute for all the water in the world. Liquids, too, seem to be out of the question as sources of our substitute for water, because water itself is by far the most plentiful liquid in the world.

Do you think there is enough scientific knowledge and practical resourcefulness in the whole world to permit us to make a liquid that will incorporate at once all these necessary qualities that water has, and still that will not have a single undesirable quality to clash with other things in nature or to upset in the least her great and intricate cycle? To this question there seems to be but one logical answer: "No."

WEATHER HAZARDS IN AVIATION

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THERE are two principal sources of danger in civil aviation: first and most important up to the present time, those connected with the machine itself, *i.e.*, the plane or ship; and second, those arising from discontinuities in the medium —the air—in which plane and ship function, or what we call adverse weather conditions.

The second source will probably soon become the more important inasmuch as there is a betterment each year in the steadiness of performance of the machines. On the other hand, there is little prospect of control of the atmosphere, and all that can be done is to give warning of the likelihood of dangerous conditions. After that it becomes a matter of judgment on the part of the pilot as to what route, if any, will be attempted.

In various papers the writer has set forth at some length the need at airports of *up-to-the-minute airgraphics*, that is, continuous observing and recording of the physical processes involved in the condensation of water vapor in the free air, for it is our belief that a short and serviceable definition of weather is—change in state of water vapor. It is water, whether as cloud, invisible vapor, hail, sleet, glaze, snow or rain, driven by the air stream and responding to temperature discontinuities, which makes weather and does mischief. Even in the acquisition of a charge of electricity and the making of a disruptive discharge like lightning, it is the cloud droplet which is the villain in the play.

Cloud formations, therefore, must be studied *intensively* at all airports; not only must height, direction and velocity be given, but serious effort must be made to read in the cloud itself the story of the stratification of the vapor, the temperatures, the percentages of saturation, the densities per unit volume and the electrification of the cloud droplets. This might well be called vapor structure. An example is readily found in the cumulo-nimbus cloud, which is an upthrust of cloud-stuff into higher strata, indicating accumulation of electrical charges just as plainly as a salt dome indicates the proximity of oil in geological structure.

At present, condensed water vapor, or cloud, is the best agency by which the observer on the ground can tell what the air streams are doing at various levels. True, pilot balloons and sounding balloons are in use to detect air currents and thus far have been the main reliance of aerographers; but in addition to expense and uncertainty of data, pilot balloons give no temperature or vapor-content data, and sounding balloons give records that are not available until many hours or days have elapsed. It is necessary, therefore, to rely chiefly upon cloud measurements. Blue Hill Observatory, under the late Professor Lawrence Rotch, was the pioneer and for a long time the only institution in this country using sounding and pilot balloons, and it is fitting that a plea for the use of improved cloud-measuring apparatus should come from this observatory. When clouds are not present, artificial clouds must be formed by smoke trails from rockets and shell bursts.

The weather hazards then to be considered are thunderstorms and lightning, fog and ice formations and *anakatabats*, or up-and-down air rushes.

Lightning

Are aeroplanes and airships liable to be struck by lightning? The answer is, "Yes!" If it can be avoided, airmen should not fly close to cumulo-nimbus clouds, or attempt to pass between layers of dark clouds of the nimbo-stratus type. (The word nimbus is now considered by aerographers as an adjective rather than a noun and indicates any type of cloud from which rain is falling, so that, to be more accurate, we should say nimbus cloud sheets, whether cumulus, stratus, pallio or grandineus). Fortunately, the great majority of cloud types are harmless and apparently without noticeable electrical charge.

We do not know positively how a cumulo-nimbus cloud becomes electrified, the acquisition being both rapid and intense. We do know that friction of one solid with another will produce electrification, especially in cold, dry air. It is also known that friction of a jet of steam or even cold water against a metal surface produces electricity. Dust clouds in motion become strongly electrified, and we can by circulating air vigorously against frost crystals produce intense electrification; but there is still much to be learned regarding the mobility of ions in the free air, the way in which charges originate on these carriers and the way in which, once acquired, the charge increases.

Dr. G. C. Simpson, as early as 1909, showed that by breaking up water drops in an air current there is developed an electrical separation, the drops becoming positively charged, while the air is negative. On the theory advocated by Elster and Geitel, the prime cause of the development of a high charge is to be found in the collision of rain drops in an existing field. Whatever the nature of breaking the droplets may be, the presence of an ascending current of approximately ten meters per second seems to be essential in connection with the change in electrification of an ordinary cumulus cloud to a cumulo-nimbus. The droplets for the most part are positively charged. Simpson has given several diagrams illustrating the air currents moving in at the ground, then rising until the base of the cloud is reached and penetrating with a filter effect. In the cloud the smaller drops are prevented from falling. There is separation of cloud particles and water, and there results an accumulation of positive electricity in that part where heavy rain, positively charged, begins to fall. The cloud remains negative. Simpson holds that flashes start from one portion of the cloud and are branched upward toward the negative charge in the main cloud, or downward toward the ground. He bases this on photographic evidence, but the conclusions are not beyond criticism. The accumulated positive charge in the region of separation is dissipated constantly by lightning, the cloud remaining negatively charged. On the other hand, Wilson is of opinion that the raindrops are negatively charged and the smaller particles positively charged, the clouds being thus of positive polarity.

It is evident that authorities are not agreed and that there has been more speculation than experimental determination of potential values in close proximity to the cloud base.

It may be mentioned, however, that during thunder-storms and in less degree during snow-storms, the potential gradient at a height of 500 meters often exceeds 10,000 volts per meter. It is evident, then, that a plane under a charged cloud is in a strong electrical field and by its very presence tends to break down the dielectric; and when a discharge does occur, the plane may be part of the path. Judging from what happens to kite wires, we think it quite likely that guy wires and metal parts of

small cross section will be fused under such conditions. Some rough calculations of the energy and voltage in the case of kite wire struck by lightning give 6.48×10^6 kilovolt amperes, approximately 7.5 kilowatt hours. The values will vary, however, depending upon the time factor. Thus if the time be extremely short, as it generally is, the voltage runs up to 13,000,000 instead of the 1,400,000, and the energy 25×10^6 KVA.

There are several instances of planes struck by lightning, with fracture of struts, fused wires and shattered ailerons, but thus far without loss of life. Whether such planes experienced intense flashes, or side-flashes of moderate intensity, must remain an open question. There are all degrees of lightning, from feeble to intense, from the tremendous rush of energy known as an impulsive rush discharge to the meandering horizontal flashes with many small ramifications.

Those of us who have studied the effects of lightning are almost inclined to believe that lightning is a law unto itself. Its vagaries are so numerous that the usual laws of current flow are not applicable. In some cases, a definition of lightning as an *electrical explosion* best describes the phenomenon, while at other times the current (or probably an induced surge) will travel long distances and be measurable. Additional knowledge is being gained daily by the experiments conducted by both the General Electric Company at Pittsfield, Massachusetts, and the Westinghouse Company of Pittsburgh, Pennsylvania. Discharges of 5,000,000 volts are available for experimental purposes. New timing devices, such as the cathode ray oscillograph (a beam of cathode rays deflected in a strong electrostatic field, the particles being electrons and practically without mass), enable the experimenters to record in microseconds, *i.e.*, millionths of a second. Peek's experimental work with near lightning is a far call from Franklin's "fire of electricity" described in one of his letters (July 29, 1750) antedating the kite letter two years. As previously stated, the time factor is all important in determining the character of a lightning flash. If some one will discover a means of damping or slowing down the rush of the negative electrons, the problem of harnessing lightning will be solved, for the energy involved is not greater than can be controlled. Also if means can ever be devised to interfere with the process of accumulation of charge on a cloud surface, we shall then be able to rob the thunder-cloud of its present potential danger.

There are some interesting changes in the electrical potential of the air just in advance of a cumulo-nimbus cloud, and in fact it is possible to measure the strength of the field and by watching the increasing voltage forecast as much as thirty seconds in advance the discharges. With each lightning flash the electrical tension is ended, but only for the moment, as it begins to rise again slowly if the cloud is some distance away and almost instantaneously when the cloud is overhead. There is, however, as yet no way of telling from what part of the cloud the flash will start.

Fog and Ice Storms

Fog has been considered up to the present time the cause of more mishaps than any other atmospheric condition. This menace is being steadily minimized by the introduction of ray-beacon flying and the use of new devices for determining accurately distance above ground. It is also possible to dissipate fog; and although experiments in this direction in the open have not as yet given satisfactory results, the expenditure of energy

being out of proportion to the results achieved, there is no doubt in the writer's mind that here, as with the lightning, it is only a matter of time and further experimentation before we shall have devices for this purpose operating in commercial aviation.

There are many kinds of fog, all formed by cooling of the water vapor, however the cooling may be brought about. It is important to know the number and activation of the hygroscopic nuclei, also the larger ions and dust particles. Here is a fine field for investigation, in the relation of the size of the fog droplet, the radius of curvature and consequently surface tension, to the electrical charge together with the chemical properties of the nuclei.

We are not certain whether ordinary dust particles suspended in the air are efficient condensation nuclei. It is not definitely known whether activation is a function of size or of chemical property and origin. We do know that smoke and the gaseous products of combustion make efficient kerns or centers, that is, good condensation nuclei. Possibly this is due to traces of chlorine, for the hygroscopic feature of sea-fog droplets is undoubtedly due to the presence of salt. Experiments made by the writer with electrified and non-electrified smoke indicate that the latter greatly accelerates fog building. As is well known, rapid expansion and consequent quick cooling of an air-vapor mixture cause temporary cloud or fog. The introduction of smoke and small hygroscopic kerns makes the fog denser and more persistent. On the other hand, the problem of fog dissipation finds a solution by rapid compression, dynamic heating and clarification due to electrifying. It also seems to be established that the passage of a plane through a cloud under certain conditions will result in the formation of a clear channel, due mainly to mechanical fractionation of the cloud-stuff. The nuclei with their vapor spheres and probably the intervening air cushions are both broken and scattered.

There are, of course, many types of fog formation. Those which directly affect airmen are ground radiation fogs and sea fogs. The former are dangerous in the matter of landing, but to a large extent this hazard is being reduced by the use of locating devices both on the field and on the plane. Radiation fogs are seldom very deep, and having sharply defined limits are easily surmounted. Sea fogs are chiefly due to a warm air-vapor mixture brought down to or over a cold water surface. In coastal flying or on transoceanic flights, it is only necessary to rise a few hundred meters to be above the fog. Both types are found when anticyclonic pressure prevails, or when lows are moribund, the radiation fogs generally without wind, the sea fogs sometimes with steady north or northeast winds.

Ice Storms

A plane may acquire in a brief time a load of ice which not only interferes with the instruments but also increases the parasitic resistance and deforms the aerodynamic lines of least resistance. This happens when a plane passes through a mass of subcooled vapor, whether visible as cloud or invisible. The rush of the plane probably destroys the droplet structure, and the vapor tension (which is considerable in the case of extremely small drops) is released, and a change of physical state results. Hence any surface in close proximity becomes coated with ice. This may form even on the hub of the propeller.

Several methods for ridding or preventing the formation have been tried, particularly coating with vaseline or oil, but without evident success. One must

watch thermometers carefully and particularly the wet bulb when flying through clouds in which the temperature is slightly above the ice point.

Ice Storms Proper

Somewhat different from the subcooling ice load described above is the load of ice which is acquired when flying through an ice-storm. We now deal with water that has not been long in the liquid stage, forming and falling at first as rain but passing through cold air strata and also coming to rest on a cold surface. This is glaze—or what was formerly called sleet. A coating of ice of this kind may soon become quite thick as the coating continues to grow, and by its mere weight it can force down the plane. Heating may be resorted to in the case of all-metal planes, and the ice melted, but the easier and more practical course is to rise to an upper, warmer stratum. Conditions favorable for ice-storms can be forecast with a high percentage verification, as they are zones of marked instability accompanying energetic cyclones in which temperature fronts are sharply defined and the progressive movement of the discontinuities can be anticipated. The aviator must be on the watch for warm, moist, southerly winds with underrunning cold, dry, northwest winds.

Anakatabats

This word from the Greek for up-and-down marches best describes the violent up-rushes and counter down-rushes of the air occurring when excessive temperature discontinuities exist, as in the case of thunder-storms, line squalls and all tornadic formations. The instability is such that with the slightest horizontal movement a torque is developed with rotary motion that may have a horizontal axis instead of the more common vertical. These major turbulences are quite frequent on summer afternoons in slow-moving or stagnant low pressure areas. They are essentially local in character, being different in this respect from the line squalls to be discussed later. Any marked convergence of horizontal air streams is quite likely to develop a strong up-rush, which in turn must increase the downward rush of air in the rear of the convergence.

Experienced pilots have stated that they have dropped as much as 700 meters in a minute or so when caught in one of these anakatabats following a thunder-storm. The wreck of the *Shenandoah* can be traced to the anakatabats in the southwest quadrant of a low which passed eastward slowly on the morning of September 3, 1925. A streaky cloud appeared in the north, building up rapidly. Without much warning the ship began to rise. An effort was made to keep the ship down by increasing the engine speed and turning the nose of the ship down at an angle of 18°. The uplift was still sufficiently great to overcome the effort, and in fact increased. Nor did the valving of gas help. Then came a fall accelerated by the down-rush of air as well as by loss of buoyancy. Water ballast was dumped from the control car. Probably this was a mistake, for caught in another up-rush, the ship rose rapidly to nearly 1,900 meters, only to be struck by a descending current of such violence that it began to spin violently, around a vertical axis, in a counter-clockwise direction while falling. The rotational strains caused structural breakage, followed by collapse of the control car struts and consequent tearing away and ultimate crashing.

We can by electrical apparatus give warning in advance of conditions favoring the development of thunder-storms and these anakatabats. In addition the

rate of advance of a cold front can be rather accurately estimated.

Line Squalls

These are developed on a rather long wind shift line, and while associated with thunder-storms, are as a rule restricted to much lower levels and indicate rotary motion with a horizontal rather than vertical axis. Here again it is a question of temperature discontinuities as brought about by the conflict of air streams of different origin. The wind changes direction suddenly from south or southwest to northwest or north. In other words, the western limit of warm moist winds is suddenly swept aside by the eastern front of an on-coming high. Heavy rain with marked cooling accompanies the restoration of equilibrium. The whole mechanism is not quite as simple as here indicated, for the front edge of the surface cold air may be forced upward over a part of the retreating warm air. In other words, a tongue of cold air may penetrate the warm air mass at a height of 100 meters or more, running thus in advance of the main body of cold air which eventually displaces completely the warm air from the surface up. The cloud transformations are good exponents of the turbulence and give us some notion of the structure aloft which, however, can not be seen in its entirety from the ground.

IS EVOLUTION A CONTINUOUS OR DISCONTINUOUS PROCESS?

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THE various theories of "mutation" or "saltation" were offered at first largely as alternatives to the natural selection principle as conceived by Darwin. Whereas the latter made use chiefly of the ordinary quantitative differences shown by nearly every part of every plant and animal, the earlier views of the mutation school agreed in basing evolution upon a quite different and much less abundant type of variation. The mutations, to which they appealed, were discrete steps of quite appreciable magnitude, which, in some cases at least, might transmute the entire organism. Selection, so far as it was recognized at all, was supposed to act upon the finished products of the mutative process. According to De Vries, it was a matter of the survival or non-survival of *species* rather than individuals, though the species which he had in mind were commonly subdivisions of the groups so recognized by taxonomists.

In favor of such a view-point a great variety of arguments was offered. So far as these related to the supposed inadequacy of the natural selection hypothesis, they had, for the most part, been discussed by Darwin himself. Although now familiar to every student of the literature of evolution, it may be allowable to summarize here a few of those objections to the natural selection theory which were supposed to be avoided by the theory of mutation.

(1) The difficulty of believing that the incipient stages of useful organs or characters can be subject to selection.

(2) The common occurrence of useless characters, including many of those by which species are distinguished from one another. Allied to this is the over-development of certain structures, which may thus become not only useless but positively harmful.

(3) The inability of selection to account for the discontinuity between species in nature. Why the gaps which are everywhere seen?

(4) The assumption that nothing qualitatively new can possibly result from the selection of quantitative grades in the development of an existing character.

(5) The experimental demonstration of the fact that the efficacy of selection, when crossing with other strains is excluded, is commonly limited to a very few generations. In many cases, indeed, a reversion to the original type is encountered as soon as selection is discontinued.

(6) In addition to such arguments as these, the mutationists were able to point to the actual occurrence of variations which appeared to conform to the required type. A vast array of such evidence was accumulated.

Those who were opposed to the mutation view, in this earlier form, could fairly reply (among other things):

(1) That the theory of sudden, fairly large changes renders even more difficult our understanding of complex, harmoniously working organ systems.

(2) That paleontology, despite the prevailing incompleteness of its records, offers much evidence for the continuity of development. What appear to be perfectly continuous series of extinct forms

have been found, in certain cases, where the conditions of preservation were particularly favorable.

(3) That existing geographic variations are largely of the continuous type. One geographic race frequently grades into another through insensible steps.

(4) That the existence of mutants, sports or freaks, within species, had long been recognized by systematic zoologists and collectors. Sometimes the same mutant type was known to crop out in a number of related species, paying no attention whatever to specific lines. The nature and mode of occurrence of these aberrations seemed to place them in a different class from the characters by which species or other natural groups were distinguished.

(5) That the results of crossing natural species are found to be quite different from the results of crossing artificial races, which differ by one or more simple characters believed to have arisen through mutation. No obvious Mendelian segregation is evident in crosses of the former class.

(6) That practically all the best-known illustrations of the phenomenon of "mutation" are of the nature of losses or abnormalities, which would tend to unfit the possessor for living in any natural environment.

This divergence of view-point in respect to evolution was paralleled by a similar divergence in respect to heredity. Mutationists, since the resurrection of Mendelism, have probably all been supporters of the view that the entire heritage of an organism consists of discrete, practically unchangeable unit factors, which combine and separate in biparental reproduction, according to the laws of chance, without affecting one another.

Those who opposed the mutation standpoint for the most part minimized the stability of the hereditary units, claiming that the latter were subject to quantitative changes or to mutual contamination in crosses, or even that inheritance of the Mendelian sort (dependent upon genes) represented but a fraction of the entire process of inheritance.

I think it may fairly be said that the truth, as now generally accepted, is intermediate between the extreme positions stated above. The outcome of this controversy has been something of a compromise as regards the really essential points at issue, though I am not sure that one side, at least, would concede this to be true. The mutationists were probably more nearly correct, so far as fundamental principles were concerned. But they were, at the outset, decidedly reckless in the application of these principles, calling into question facts which did not, at the time, seem reconcilable with them.

It now seems likely that those who have argued for the existence of discrete units, both of evolution and heredity, are correct in principle. Chemists have their molecules and atoms, and physicists their positive and negative electrons and their quanta of energy. Not only is the theory of abruptly mutating genes in keeping with the present trend of thought in the physical sciences, but it has in its favor a large array of experimental evidence.

On the other hand, the proponents of both mutationism and Mendelism have had to recast their conceptions to such an extent that they have conceded nearly all which is required for the purposes of Darwinian selection, and have left the outlook both for taxonomy and phylogeny virtually undisturbed. Mutations are no longer large, abrupt affairs, affecting in a visible way many parts of the organism. The great majority of them are vanishingly small. The "continuous" or "fluctuating" variabil-

ity of every part of every organism is no more to be rejected as material upon which selection may work. It is now known to be due to transmissible or genetic differences, as well as to modifications imposed by the environment, during the single lifetime.

Different grades in the size of a given part, or the degree of development of a given character, so far as these are hereditary, are now attributed to the influence of numerous genetic factors, each small in effect when taken singly, but cumulative in their action. After a cross between two species or races, these factors segregate according to the laws of chance, giving rise to every possible combination, but with little probability of the return of either parent type in its pure form.

Moreover, the stability and discreteness of the single gene, or genetic factor, has had to undergo considerable curtailment. Modern research has shown that certain genes (*e.g.*, those responsible for eye color in *Drosophila*) are subject to whole series of finely graded quantitative changes. The case for discontinuity is saved by the assumption that there is a definite number of such possible grades, corresponding, perhaps, to the number of possible molecular combinations.

Furthermore, the German geneticist Goldschmidt, from extensive studies of heredity and sex in Lepidoptera, has come to the conclusion that the same genes (or rather corresponding genes), in related species or races, may have different quantitative values or potencies.

Arguing from such facts as the foregoing, some biologists have very recently begun to emulate the physicists by calling into being a system of secondary genes or "genomeres," into which the mind's eye may resolve our hitherto recognized hereditary factors.

With this revised conception of the nature of the unit factors of heredity, it is evident that the type of hereditary variation available for the operation of selection has likewise undergone an extensive revision. We hear much less said of the survival or elimination of a *species*, the latter having first sprung into existence, full-fledged, through a single mutation. Rather is a species believed to be commonly built up through the accumulation of a large number of slight, independent mutations. Even two closely related geographic races of mice, if we can depend upon the evidence of hybridization experiments, differ by a considerable number of hereditary factors, each due, presumably, to an independent mutative change. Thus the rôle of selection has been not merely to determine which ready-made species shall become established as members of our fauna and flora. This or some other directive agency has been necessary throughout the entire process of the differentiation of one form from another.

Furthermore, one may be a consistent mutationist of the modern school, and yet believe that many species arise without any immediate participation of the process of mutation at all. Recent discussions in the field of philosophical biology have stressed the importance of a principle which, although simple and readily intelligible, had been largely overlooked by earlier writers. I refer to the principle now so frequently discussed under the name of "creative synthesis" or "emergent evolution," or by some other name. This is nothing more than a full recognition of the fact that entirely new qualities may be the outcome of new combinations of existing elements.

Within every natural population there is much genetic diversity. Let us grant that differences between homologous genetic factors or genes have been due,

in the first instance, to the process of mutation. But the almost infinite diversity of the combinations of these factors is due to the continual process of mixing and unmixing which is the essence of sexual reproduction. Far-reaching changes may thus result from selecting and perpetuating certain ones among these genetic combinations and eliminating others. Indeed, there is an active group of biologists, headed by the Dutch geneticist Lotsy, who attribute all evolution to this process of recombining existing factors, and who question or deny the modification of factors or the origin of new ones. Without going to such lengths as do these writers, we may concede that factorial recombinations, following crosses between genetically different individuals, have probably played a far greater rôle in evolution than has commonly been assigned to them. It is likely that many, perhaps most, of the novelties which are carelessly called "mutations" owe their origin to this cause.

How then, it may be asked, does up-to-date mutation differ from the type of variation which Darwin believed to furnish the basis for his theory of natural selection? The two certainly differ much less than the original mutationists supposed. But are there no differences left? Has all the controversy of the last quarter century left this question exactly where it stood? This is hardly the case. We now realize far better than Darwin did that there are two sharply contrasted classes of variations. To the one class belong the non-hereditary variations which, it is commonly assumed, are all due to the action of the environment, broadly speaking, upon the individual. To the other class belong the hereditary variations or "mutations." The latter term has been commonly retained, even though the point of view of those responsible for this name has been largely abandoned. Mutation, according to current usage, is nothing more than hereditary variation, regardless of magnitude. It may be defined as hereditary (transmissible) modification of the germinal substance; or since any actual modification of the germinal substance is presumed to be hereditary, the latter word may be omitted from the definition. Conversely, any modification of the germinal substance, however produced, would by definition be a mutation.

Another advance over the selection view, as conceived by Darwin, is a clearer realization of the limitations of selection, in producing continuous change in a given direction. The great majority of experiments in this field have shown that the effects of selection, while at first they may be rapid, soon come to an end. A level is reached in the character dealt with at which it ceases to advance, at least with any regularity or certainty. This situation is now explained on the basis already indicated, namely, that we have to do with a sorting process, by means of which particular genetic combinations are separated out from a mixed population and perpetuated. In the course of this process no new elements commonly appear upon the scene, though new combinations of previously existing elements may give rise to strikingly new qualities. After the sorting process has been brought to an end, no further change is possible, in inbred stock at least, without the advent of further mutations; in other words some of the existing factors must undergo change. But this is a rare phenomenon and may not occur in the course of a short-time experiment. Needless to say, new genetic combinations may be introduced at any stage by crossing with other strains, but changes so produced are to be ascribed to hybridization rather than to selection.

It can hardly be disputed that this revised version of mutationism, with its minutely graded series of independent genetic changes, is subject to most of the objections which were brought against natural selection in its Darwinian form, and which were supposed to be avoided by the original mutationism of the saltatory type; for example, the difficulty of explaining the pre-useful stages of useful structures, or the commonly present discontinuity between the species of our taxonomists. These difficulties regain all their former force so soon as we base the process of evolution upon the accumulation of scarcely perceptible differences, all quite independent of one another. It would seem fairly obvious that we can not retain the advantages of a saltation theory of evolution while contending, in the same breath, that the mutations which furnish the raw materials for the evolutionary process are for the most part insignificantly small.

It is surprising to find traces of an incomplete adjustment between the older and newer view-points in the writings of one who has led the way in the detection and analysis of minute mutations, and whose polemical writings have had much to do with convincing biologists in general of the factorial basis underlying quantitative variability. Morgan's volume, "Evolution and Genetics" (1925), contains a lucid and interesting exposition of his more recent point of view regarding these questions, while retaining certain of his earlier modes of expression concerning the rôle of discontinuous variation in evolution.

How else than as an argument for evolution through large steps can the following utterance be construed? "Suppose that evolution 'in the open' had taken place in the same way, by means of *discontinuous* variation. What value then would the evidence from comparative anatomy have in so far as it is based on a continuous series of variants of any organ?"[1]

Morgan had just been discussing various mutations in wing length and other characters in *Drosophila*. Some of the former have resulted in dwarfing the wings to various degrees, down to the complete loss of these appendages. But despite the fact that we are able to arrange these abnormalities in an almost complete series as regards size, "the order in which these mutations occurred bears no relation to their size; each originated independently from the wild type." This discussion leads to his query regarding the evidence from comparative anatomy.

To this query of his I think we may reply as follows, and I venture to believe that the Morgan of 1929 would scarcely dissent: Our ability to pick out forms which may be arranged in a continuous series manifestly does not in every case prove that this series represents the actual course of descent. But unless we are prepared to admit that such differences as those between the larger subdivisions of the animal kingdom have arisen discontinuously, we are fully justified in holding that gradations in the degree of development of a character are frequently important and often quite reliable indications of the direction of evolution. And this is particularly true where, as is commonly the case, several different characters have undergone simultaneous change.

Morgan's own use of the classical case of the reduction of digits in the horse shows that he has no thought of the modern one-toed condition having arisen as a single mutation from the original five-toed condition. But if not, then various intermediate stages must have occurred in the past, and the testimony

[1] "Evolution and Genetics," p. 22. (Unmodified from "A Critique of the Theory of Evolution," 1916, p. 13.)

of paleontologists points strongly to the conclusion that the right stages occurred at the right time, historically speaking. Is it, therefore, fair to say that the degree of discontinuity which seems probable in the light of modern genetics invalidates to any great extent the testimony of comparative anatomy to conclusions regarding phylogeny? We may cite Morgan's own words in reply:

> This argument for rejecting extreme or monstrous forms seems to us to-day as valid as it did to Darwin, but we now recognize that sports are only extreme types of mutation, and that even the smallest changes that add to or subtract from a part in the smallest measurable degree may also arise by mutation. We identify these smaller mutational changes as the most probable variants that make a theory of evolution possible.[2]

The data of present-day genetics are certainly in no way inconsistent with the belief that the transformation from one species to another has commonly involved no greater break in continuity than we may now observe between one individual and another within the same species. Can any positive evidence for such a belief be offered? The evidence which I shall briefly cite falls under two heads: (1) genetic, (2) geographic. Let us consider these in the order named.

According to the currently accepted Mendelian interpretation, the mutation of a single gene or factor results in a variation which is allelomorphic (alternative) to the wild type, and which gives, when mated to the latter, the simple 3:1 ratio. When, on the contrary, the difference between two races is such that, if crossed, a blended or intermediate condition results, out of which the parental types can not be recovered, or only with difficulty, we must attribute this difference to changes in a number of genes, in other words, to a number of independent mutations.

[2] *Op. cit.*, p. 130.

Now it happens that not a single case has been reported, so far as I know, in which two taxonomic species have been crossed and have been found to differ by a single pair of Mendelian factors. In other words, not a single case is known in which one species has arisen from another by a single mutation. But the case is vastly stronger than this. Two species commonly differ from one another in a considerable number of visible and measurable characters, relating to various parts of the body. In most cases where the hybridization test has been made, not only are these various characters inherited for the most part independently of one another, but each of them, taken singly, conforms to the multiple factor scheme. In very few instances does any one of the specific differences behave in heredity as if it had resulted from a single factor mutation.

In the course of my own breeding experiments, I have hybridized forms more closely related to one another than are most species. But even these geographic races differ from one another in every instance by a number of different characters, while each character, as in the case of species, is certainly dependent upon more than one Mendelian factor. Thus, if the mutation view is correct, it has required quite a series of mutations to bring about the comparatively slight differences between two adjacent geographic races. (I must repeat that the actual process of mutation did not necessarily occur at the time that the newer race became differentiated. There may have been merely a reassortment of existing genetic factors by some form of selection.)

The second line of evidence on which I rely is that of geographic variation. The student of this field knows that graded series occur in space, not occasionally but frequently, and that these

are correlated in many cases with environmental gradients.[3] In some cases, the conclusion seems unavoidable that the series in question gives us an actual picture of the steps by which one of the extremes became differentiated from the other. That there is no essential difference between such racial differences and those which distinguish "good" Linnean species will be questioned by few who are acquainted with the facts. Whether two forms be regarded as distinct species or merely as subspecies is largely a matter of convention. It seems highly probable that the formation of these geographic races or subspecies represents one among the various modes in which the divergence of species and even larger categories of living beings has had its inception.

Let us, then, return to the question with which we started: Is the process of evolution continuous or discontinuous? In my opinion, the correct answer to this question is much the same as that to the question: Is matter continuous or discontinuous? In both cases, we have to do with a sensible continuity, based upon an underlying discontinuity. I have already indicated my belief that the transition from one species to another has commonly involved no greater breaks in continuity than we may now observe between one individual and another within the same species. The idea that not only widely distinct species, but new genera, families and even higher categories have come into existence suddenly may relieve us of the embarrassment of not finding intermediate forms, but it is not supported by a single direct observation. The suggestion of Lotsy[4] that new classes and phyla have originated abruptly from recombinations of factors brought about by the crossing of species does not seem to have a much firmer scientific foundation than that of Geoffroy St. Hilaire regarding the hatching of the original bird from the egg of a reptile. Neither Darwinian selection nor Lamarckism nor both combined involves us in assumptions half as incredible.

[3] In a recent paper (Proceedings of the National Academy of Sciences, February, 1929) I have discussed an illustrative case in which seven different grades were found in respect to certain characters. While the full meaning of this case is still far from clear, the evidence is all against the supposition that the extremes (or even any two contiguous populations) were differentiated from one another through a single mutation.

[4] "Evolution by Means of Hybridization," 1916 (particularly pp. 119, 135, 147). I need hardly say that it is far from my intention to belittle Lotsy's extensive and important contributions to the literature of evolution.

GROWTH CURVES OF INSTITUTIONS

By Dr. F. STUART CHAPIN

SOCIAL SCIENCE ABSTRACTS, NEW YORK

I. Setting and Importance of the Problem

Whether our special interest be economic geology, poultry husbandry, mathematical physics or the economics of advertising, our lives are inextricably interwoven with social institutions which, at the same time that they hem us in, also serve as channels for self-expression. Distinguished scholars whose connection with some great university seems secure are suddenly cast into academic outer darkness because by some act they have transgressed the mores of the family institution. Men of mediocre ability often attain amazing heights of power and influence when they become the spokesmen of a political institution whose secret inner passages they have learned and to whose law of being they conform. Experiences of this sort have given food for the thought that institutions are permanent and massive elemental things. Radicals rage against them, moralists extol them, philosophers weigh them in the scales of verbal dialectic. The important question is—can we measure them? If we can measure them a new avenue of understanding is opened up and questions of the stability, permanence or change in social institutions may be answered in terms objective rather than subjective.

The following paper outlines the procedure and results of a preliminary attack on the problem of measuring changes in social institutions.

II. Research Method or Attack

The first step in scientific work is to set up a working hypothesis. We therefore state our working hypothesis thus: Social institutions pass through a cycle of change in structure and function.

Inasmuch as the unit of observation is an important consideration in scientific research we have selected for analysis four political institutions representing two different sorts of units.

Our unit of observation selected is a social invention. Mechanical inventions are such familiar and tangible objects as the automobile, telephone, radio, etc. Social inventions by comparison are not as generally recognized but they exist in great numbers; examples are the stock exchange, juvenile court, commission plan of city government, city manager plan, non-partisan ballot and many other innovations that have broken down the sway of hoary custom and ancient tradition. Our procedure in studying these institutions is to count the units of observation that occur in equal intervals of time for the same area. Inasmuch as we have as yet no uniform units of measurement or, to express the situation a little differently, since we have no means of expressing changes in the phenomena of observation in terms of the standardized units of an external criterion, we must needs resort to the expedient of counting the number of similar things which occur in equal intervals of time. We therefore examine the constitution or charter and the legislative record or ordinances, and count the number of new commissions, bureaus, departments or activities that are added each year. This is the first step toward eventual measurement and at least has the merit of describing the phenomena

in terms of verifiable facts rather than of evaluating them in terms of opinion.

III. Results

New animal organisms begin with the fusion of the female ovum and the male sperm. New social and political institutions appear to begin with the fusion of old ideas into a new mental pattern or what is popularly known as invention. In 1900 a new form of municipal government was invented[1] (at Galveston, Texas) and became known as the commission plan. Since 1900 it has gone through a cycle of growth and decline. When we plot, year by year, the number of communities that adopted the new plan we find that this plot takes the form of a roughly symmetrical frequency curve.[2] When the yearly increments are cumulated we find a growth curve similar to the growth curves that Pearl and other scientists have found for biological organisms. In this case, however, the units of growth are towns and cities adopting the plan. Thus our growth curve for the commission plan is a population growth curve in which the unit of count is a town or city and not a human individual. We have found similarly that the city manager plan, an offshoot of the commission plan, follows the same principle of growth.

These illustrations of the principle of the organic growth of social institutions are suggestive but do not offer convincing evidence because the growth phenomena consist in the spread of the new pattern over an area by diffusion and not by increase and elaboration of parts within one whole. Fortunately our research supplies evidence which meets this test. We have analyzed the changes that have occurred in the structure and function of two other political institutions each of which is an institutional entity in itself and may be regarded as a functional unit in American political life. We have taken the government of the city of Detroit[3] and the government of the state of Minnesota.[4] Our data for the city of Detroit cover the period beginning in 1824, and for the state of Minnesota beginning in 1858. Unlike the two former instances the increases of units at regular time intervals do not in the cases of Detroit and Minnesota follow a frequency cycle curve. Possibly we are dealing with phenomena having a longer life span, or perhaps another principle operates. When, however, increments of change are cumulated we find that these political structures follow growth curves similar to the first halves of the growth curves of the commission and city manager plans. The first point of inflection of the normal growth curve is passed but the second point of inflection is not attained. Consequently we can not summarize the phenomena by a Gomperz or a Pearl-Reed curve but find that a parabola is the best fit.[5]

Our data for Detroit and Minnesota consist of units less homogeneous than in the case of the commission and city manager data, because different functions and elaborations are added together to find the ordinates of the growth curves. On the other hand, we are dealing in each case with the growth of one political institution having real unity and not with the diffusion of a pattern to similar units of different size spread over an area. Consequently our study of growth of the institution of government in Detroit and Minnesota concerns phenomena

[1] E. S. Bradford, "Commission Government in American Cities," New York, 1916, pp. 3–23.

[2] F. S. Chapin, "Cultural Change," New York, 1928, p. 370.

[3] Upson, "The Growth of the City," and Chapin, "Cultural Change," pp. 361–363.

[4] M. B. Lambie, "Administration of the State of Minnesota," 1924, p. 6.

[5] F. S. Chapin, "Cultural Change," pp. 377–379.

similar to those considered in studies of growth in bodily weight of animal organisms. For this reason these last-mentioned studies are more significant evidence of the existence of a principle of growth of social institutions.

IV. Interpretations and Results

Why do institutions grow like organisms? An adult animal organism which began as a single cell attains its growth as the result of cell division and specialization. By contrast a social institution may begin as an invention—a mental pattern of a social relationship of interacting human organisms. These interacting human beings exhibit attitudes toward one another and their overt behavior gets conventionalized by interstimulation and response into such explicit social patterns as folk-ways and mores. Behavior of an emotional sort gets conditioned to such symbols as the flag or idol, depending upon whether it is a political or religious institution that concerns us. Thus it is that symbolic culture traits appear. Creature wants are met by the construction of dwellings, buildings and furnishing tools and equipment of various sorts. Thus it is that material culture traits are provided. Finally men commit to oral tradition or set down in writing their creeds, charters, constitutions or agreements and thus it happens that there are stored externally to the minds that created them the rules of relationship which constitute the underlying pattern of the institution. If we summarize our analysis of the institution in four terms: human attitudes, symbolic objects, useful objects and oral or written descriptions of the interrelationships of these three things, then it is not difficult to see why and how the social institution grows. It grows because it is the most complex form of human accommodation to a changing world. Population increases, gains by immigration, losses from wars and climatic disturbances and other events necessitate a readjustment of the original pattern of human relationship. As a consequence new symbols are invented, mechanical innovations appear and relationships become more complex. New functions develop and structure and relationship must be readjusted to make old institutions continue to work. To summarize, we may say that the social institution consists of a network of complicated interrelationships of psychological dispositions and material traits of cultural significance.

The foregoing interpretation may sound abstruse. Let us offer another interpretation of a less abstruse sort. This interpretation necessitates reference to concrete material not part of the data of observation of our immediate study but material entirely relevant to the problem. We have studied the poor law legislation of England, Massachusetts, Wisconsin and Minnesota and find that in every case the same cycle of development occurs.[6] This cycle is as follows: first, the original poor law practice is enforced until exceptions accumulate; second, many variations from it are experimented with until the situation becomes so chaotic that, third, the whole mass of laws is integrated into a code which embodies the general principles. Reverting now to the case of growth of institutional structure, we find that after the initial constitution or charter is written (the original invention) there follows a period in which modifications, additions to or amplifications of the original structure take place. This is the period of rapid growth when the curve has passed the point of inflection and shoots up suddenly. This period corresponds to the phase of experimentation in poor relief legislation. Then

[6] F. S. Chapin, "Cultural Change," Chapter VIII.

comes the period of integration when the rate of growth diminishes. This period is illustrated by the consolidations that have been effected in many of our state governments, consolidations that simplify an overcomplex structure. We have recently described this principle and called it a societal reaction pattern.[7] The principle is mentioned here because it seems to offer an interpretation in terms of social psychology for the growth tendency of social institutions described in the present paper.

In conclusion, interpretation of these results can be merely provisional, for the cases studied are too few to constitute even representative samples. This qualification, however, does not invalidate the conclusion that the working hypothesis stated at the outset has been justified. Our study shows that the total changes of four political institutions for a period of years may be described as a growth tendency not unlike the growth principle of animal organisms. Whether further study of this phenomenon of social change will lead to successful formulation of a law of social growth it is premature to say. At any rate, the results of this preliminary investigation seem to the writer to be justification for more extensive research into the field by a number of independent workers. Moreover, the interest aroused by such recent books as Spengler's "The Decline of the West" and Beard's "Whither Civilization?" encourages the belief that future investigations may be made following the more concrete procedure used in the present study. If this be the case we will gradually accumulate a systematic knowledge which may lead to the discovery of the natural laws governing the life history of social institutions. When this point is attained it will be only one step more to predict growth and bring social institutions within the range of rational social control.

[7] *Ibid.*

TOOLS OF PROGRESS

By Dr. RALPH E. DANFORTH
CHESTERFIELD, MASS.

SCIENCE is the Creator's chest of tools. Human progress is man's learning to use these tools.

Large masses of folk are suspicious of the very word *science*. Call it *modern* science, and they suffer emotional chills and fever. They have not even seen the truth that science and knowledge are one.

Many, realizing that *they* at least have not consciously done anything to advance knowledge, are very suspicious of it as of something strange, foreign to themselves, and as such possibly a trouble-breeder. In fact, they may have heard it stated that it would weaken the foundations of the home, undermine faith, or in some way or combination of ways prove hurtful to their vital complex.

If science and knowledge are one, modern science is the recent advance of knowledge. The oldest and most sacred of knowledge was one time modern. Modern science of to-day will some time be old and sacred. If by that time people's nerves have not steadied, they will suffer emotional chills and fever when the steady increase of knowledge will seem to them to threaten that which, new to us *now*, will *then* seem old and fundamental, having been built into the very foundations of human life.

The term *science* is becoming so elastic and all-inclusive that we would not be far amiss were we to say that all truth newly gained to-day could be called science. Science has also to do with the application of truth, as well as its substance.

The universe was created long ago, is still in process of creation and may, possibly, always be in process of creation. It is no longer safe for the scientific man to say that anything can not be. We are learning that all things are possible.

The tools with which the Creator made the universe and the materials of which he made it are neatly arranged in the great tool-chest, which is the vast universe itself. Man opens the chest, or more properly opens his eyes and his mind, for the chest stands always open to those who will see, and beholds the structure and the forces which are at work therein. Familiarizing himself with the chemical elements, relatively few in number, of which the whole universe is made, with their combinations and some of their endless possibilities, man at once begins to imitate some of the compounds which the Creator had already made, and also to make new combinations, suited to new purposes of his own. "Sacrilegious!" cries the man in the street, although he may have just come from a clinic where a recently invented compound was injected into him in the treatment of an old disease, and with the word still on his lips he may board a bus, in the engine and other structures of which many new combinations of metals and forces are operative. He then goes home, uses his telephone, in which other new combinations of matter and force are functioning beautifully, to call upon his friend and tell him that modern science is making the world altogether too materialistic. This is human progress: learning to know and use the tools of the Creator. The scientist feels that the Creator intends that he should do this.

Chemical elements and their numerous

compounds, physical force, vital energy and the yet more mysterious realities of intellect, affection and soul, these are at once the tools and fabric used in shaping the universe. These are the tools and fabric which man is learning to use as he begins to understand the cooperative part which his Maker, in whose image he was made, intends him to take in the divine plan.

The tools of progress were used in shaping man as well as the rest of the universe. They are being used in shaping man to-day. They will be used in shaping man in the future. They shape his mind as well as his body, and the heart or soul of him as well as his mind.

Man himself, in cooperation with the Great Originator, may have a hand in the making and fashioning of the human race. The real difference between the statesman and the simple politician is that one thinks constructively for the good of man while the other can not see past the edge of his pocket. The measure of the statesman is his creative reach. He must have vision, heart and the genius of achievement.

All additions to the sum of truth which we possess place more tools and materials in the hands of human benefactors, whether they be statesmen, scientists, teachers or just plain mothers.

These new truths, tools or powers are popularly styled to-day modern science. And what can this new light of knowledge hurt?

What can modern science hurt? Human errors shrivel in the white light of knowledge as lint in a flame. Follies too will be hurt, for they flee the light of truth as dry leaves flee the autumn gale.

Religion, will it be hurt? The foundations of faith, will they be shaken?

Real worth in religion will never suffer from the truth, be that light of truth new or old. Intrinsic value, the true gold of faith, is not hurt by the acid test.

The flood of light, ever swelling, every moment more intense, while showing up error and superstition, will give new growth to the true "trees of righteousness," and new beauty to the flowers of faith and love. Purely artificial and dogmatic elements of ecclesiasticism may suffer, but the resulting health of the religion within the heart will justify the sacrifice many times over. The eternal heart of religion will grow prodigiously as the blankets which smother it are peeled off and consumed. That which has abiding value will increase; the gold-bricks be exposed.

But modern science rapidly swells the flood of light. This growing light of truth and knowledge and power is daily adding to human comfort. Not alone the comfort of body but comfort for mind and soul increase as truth increases. In fact the main function of truth is to increase comfort and well-being. Did not the great Teacher say he would send the "Comforter" who is "the Spirit of truth" and "will guide you into all truth."

If religion is to be benefited by the ever-brightening rays of truth, what *will* modern science hurt?

Modern science will hurt whatever the true tools of progress will injure; whatever stands athwart the fundamental plan of the universe.

It seems as though the continued approach unto all truth would hurt many things. A number of human industries will be hurt by the increase of knowledge. In this country legalized liquor trade has already been hurt. The chances of its speedy recovery seem smaller than the chance of the spread of the same injury to other leading countries. A number of other industries, which increasing knowledge may demonstrate to be destructive rather than beneficial to the best interests of man, will be seriously hurt if not actually destroyed.

The isolation of many peoples will very soon be seriously hurt by the rapidly spreading light of knowledge and communications. With the destruction of isolation many long-cherished ideas and personal habits of the erstwhile isolated ones will be hurt unto death. Like cockroaches beneath an over-turned box, fleeing before a flood of light, the deep-seated errors of benighted folk will scuttle into the dark cracks and crannies of oblivion.

Languages, now counted by hundreds, will be hurt and reduced to an irreducible minimum. The thought of mankind will then flow freely around the globe, and be the property of whoever has ears to hear. New discoveries, inventions, facts—new truth in any form, will encircle the earth at lightning speed, a light to enlighten all Jews and Gentiles who have mind enough to comprehend it and the will to absorb it.

Mental habits and bodily habits of persons right at home, as well as those of the benighted in isolated lands, will be hurt to the extent of being supplanted by better habits, when the blast of larger truth glares with spot-light intensity upon them. Many pet follies, now perfectly legal and even generally cultivated, will wither in the sunlight of the full truth. Seeing through a glass, darkly, permits many customs which a brighter light would show to be ugly rather than desirable. In the gloom below the jungle are many growths which can not endure the full light of the sun.

But all this hurt from modern science will react to our benefit. Only those who are so completely obnoxious that everything in them will be hurt by the light can really be counted sufferers. All others will rejoice in the healing beams of increased knowledge, and be glad of the changes it brings about in their thought and habit and health. Their new ways will mean new powers, more real and lasting wealth and new joys.

Modern science will hurt war. Already some serious blows have been dealt that common foe of mankind. Our old knowledge will help valiantly in destroying war, but we may need yet new light before it is completely put down.

With the increase of knowledge national boundaries will cause less concern. Patriotism and liberty will take on new meanings among the many republics and provinces and dominions. Instead of shouting loudly and wildly for *independence* and *liberty* the concept of the welfare of the individual, as something of more substantial worth, will gradually replace in men's minds what is after all but the ghost of a panacea. There is no such thing as an absolutely independent nation. Probably there never will be, unless it includes the whole earth. In traveling among little countries I have observed that it is the citizens of the countries bestowing the least real benefit upon them who do the most orating about *patriotism*, and they also do the most fighting. This orating about patriotism, and this fighting, together with drinking and gambling, are the breath of life to many in whom sentimentality exists in gigantic proportions and the practical sense appears to be altogether omitted. Modern science never has been forwarded by such folk, neither will they ever let other people apply it to their benefit if they can fight it off.

In the far East there are millions who loathe "western civilization." There are faults in the westerners, but these should not be attributed to civilization. Countless brains are too small ever to be able to discern the good from the bad. There is no alternative but for them to die in their ignorance.

Finally, brethren, what do you think of a minister who preaches science instead of religion in his church? I think him a fool, though he may be a fool who

has seen a gleam of real light. The church will never be able to vie with other institutions as a center of scientific information. And the minister usually half murders his science, unless by chance he has spent years at practical scientific work in the laboratories supplementing his text-book studies. And even were he a highly trained scientist standing in the front rank of the world of science he could not make a science take the place of true religion in the church. Modern science will never be able to hurt true religion except in those who substitute it for religion. True human progress lies in the cooperation of science and religion, not in substitution. Religion needs vitally all the new knowledge it can get, in order to grow; and if it does not grow it dies. This is the gleam of truth which the science-preaching pulpiteer espies. But his vision is very fragmentary, ruinously so. But the world of science needs true religion just as much. Without an eternal and righteous and loving spirit in his heart the scientist is little better than the clay with which he works, or a nut without a kernel. The two must be found together if anything good is to grow out of it. The future progress and happiness of man depends upon the united effort of religion and science.

What can modern science hurt? Everything that leaves it icily alone, and every one who makes it all in all and worships it as an idol. Our minds must be big enough to exceed the minds of the revolutionists who holler *liberty* when they have not the least idea what they are talking about, and the minds of those who would trample western civilization under foot as worse than worthless. There are small-minded men at home, but fortunately fewer relatively than in some other places on earth.

THE PROGRESS OF SCIENCE

THE TWENTY-FIFTH ANNIVERSARY OF THE CARNEGIE INSTITUTION OF WASHINGTON

On May 31, at Cold Spring Harbor, Long Island, the Department of Genetics of the Carnegie Institution of Washington was "at home" to invited guests. The reception was held in celebration of the conclusion of the first quarter century of the work of the institution founded by Andrew Carnegie for the conduct of research. Representatives of some sixty institutions, organizations and departments of research were among the two hundred or more guests who accepted the invitations of the president and trustees of the institution.

At eleven o'clock the guests assembled in a tent erected on the grounds. Addresses were given by General John J. Carty, representing the trustees; by Dr. E. G. Conklin, head of the department of biology, Princeton University, representing scientific men, and by Dr. John C. Merriam, president of the Carnegie Institution, representing the staff. Dr. Henry S. Pritchett, vice-chairman of the board of trustees, presided.

The remainder of the day was spent in talking with the investigators and in inspecting the exhibits which the staff had prepared to illustrate their methods of investigation and somewhat of the results that have been obtained. These exhibits were open to public inspection on June 1 and 2.

The Department of Genetics is one of the major departments of the Carnegie Institution of Washington. It was organized in 1904 and called the Station for Experimental Evolution.

Three other major activities were initiated at the same time: the Marine Biological Laboratory at Dry Tortugas, Gulf of Mexico; the Desert Botanical Laboratory (now a section of the Division of Plant Biology) at Tucson, Arizona; and the Mount Wilson Observatory at Pasadena, California. These four stations were among the first to be established by the Trustees of Carnegie Institution; they thus mark the inauguration of major research activities begun twenty-five years ago.

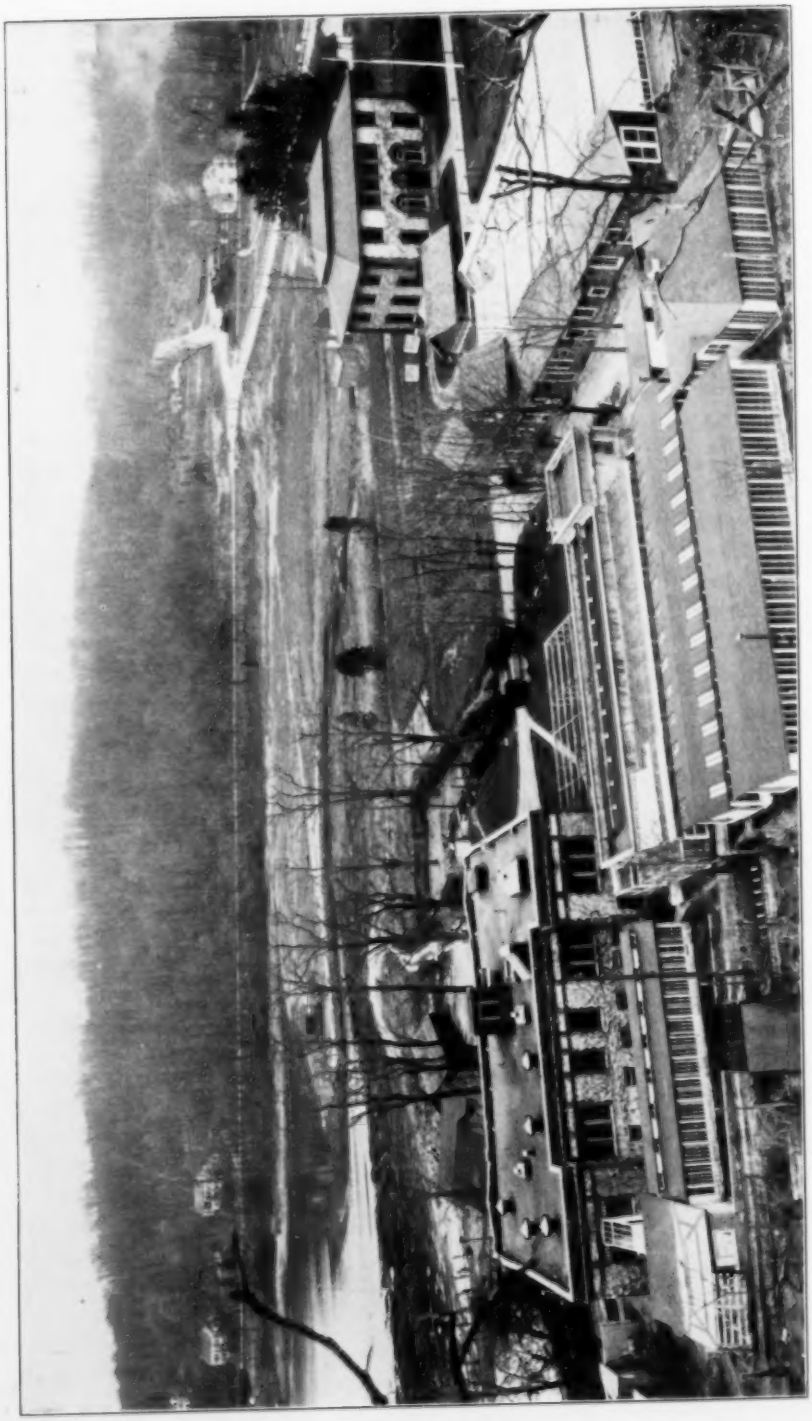
In the present organization of Carnegie Institution the major researches are grouped in ten departments or divisions with which are associated many specific investigations not of departmental type. Research is being conducted on fundamental problems in the fields of embryology, genetics and eugenics, nutrition and vitamin chemistry, plant biology, marine biology, geophysics, seismology, terrestrial magnetism, astronomy and early American history, including archeology and historical research.

The institution is also attempting to extend the usefulness of its own data of research, to increase mutual understanding among its own investigators, and to promote public appreciation of its work by holding each year, at the Administration Building in Washington, a series of lectures on topics relating to its work and an exhibition illustrating current results of its researches. For the same reasons the present exhibition has been arranged.

Almost to the day, twenty-five years ago, the formal opening of what is now the Department of Genetics took place at Cold Spring Harbor, Long Island.

Two years before, Dr. Charles B. Davenport, then of the Zoological Laboratory of Chicago, had submitted a plan of organization which was adopted. Upon invitation of the trustees, Dr. Davenport assumed the directorship, which office he has held to this day.

In 1910, Mrs. E. H. Harriman founded the Eugenics Record Office on an 80-acre tract nearby and arranged



THE COLD SPRING HARBOR LABORATORY OF THE CARNEGIE INSTITUTION

JOHN C. MERRIAM
PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

for a staff for the study of problems relating to human heredity. Eight years later Mrs. Harriman transferred the office and farm to Carnegie Institution of Washington and provided an endowment toward the maintenance of investigation. In 1921 a reorganization was effected whereby the work on human heredity and that on heredity in plants and animals were combined in a Department of Genetics.

For twenty-five years the genetics staff of the Carnegie Institution has been at work in their field. By studying the hereditary material itself in the laboratory with stains and microscope and camera; by inducing a multitude of matings among plants, insects and vertebrates and studying the offspring; by making statistical studies of racing capacity in horses; and by collecting the individual and family histories of thousands of persons and analyzing them from the standpoint of hereditary traits —by these and other methods have the members of the staff sought with gratifying success to cooperate with scientists elsewhere in penetrating the secret of inheritance and of variation.

What Makes Differences in Living Things? is the problem being investigated by the Department of Genetics and related departments. Such differences range from the great ones that separate elephants from bacteria, to such subtle ones as distinguish "identical" twins. Two paradoxical tendencies are illustrated by these extremes: the conservative tendency for like to beget like, and the restless tendency for life to appear in ever new forms. The full solution of the problem would explain how organic evolution takes place and what life is. Every phase of the study of life makes a contribution towards this solution. Some of the special fields that are being explored in search of solutions were illustrated by the exhibits grouped under the four divisions: Differences in chromosomes; Differences in environment; Differences in age; Differences in glands.

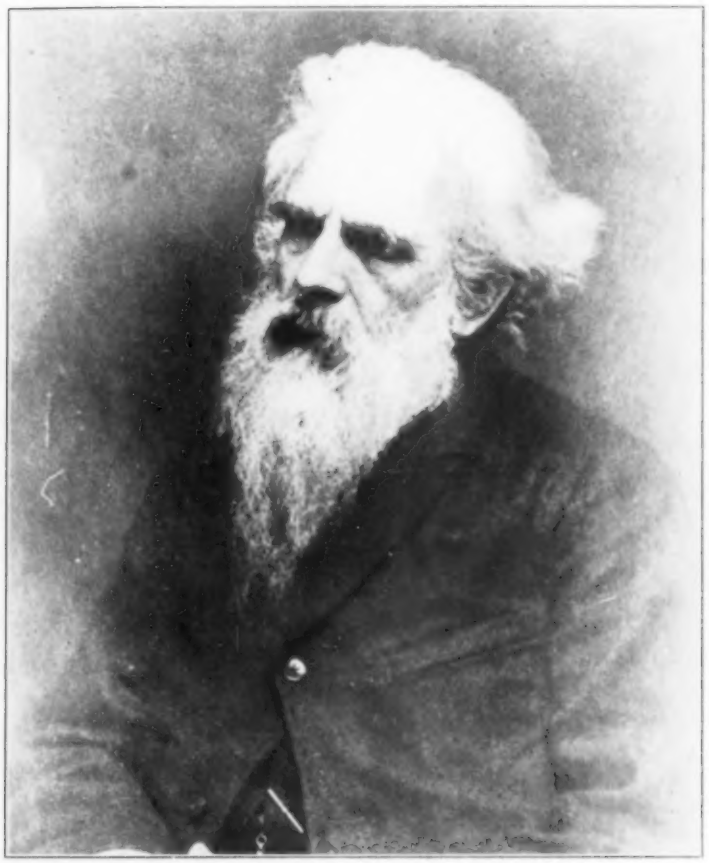
CHAS. B. DAVENPORT
DIRECTOR OF THE COLD SPRING HARBOR LABORATORY

LELAND STANFORD

BUILDER OF THE CENTRAL PACIFIC RAILWAY, UNITED STATES SENATOR AND FOUNDER OF STANFORD UNIVERSITY. THE PORTRAIT WAS PAINTED BY MEISSONIER IN 1881. THEY BECAME ACQUAINTED THROUGH THE MOTION PICTURES OF THE STANFORD HORSES. STANFORD IS HOLDING THE ALBUM OF HORSE PICTURES.

THE EARLIEST MOTION PICTURES

IN May, Stanford University held a semi-centennial celebration in commemoration of the motion picture research conducted by Leland Stanford at his Palo Alto stock farm in 1878 and 1879 with the assistance of Eadweard J. Muybridge and John D. Isaacs. It is believed that this is the first investigation to make use of consecutive instantaneous pictures and, therefore, lies at the basis of the photographic analysis of motion and also the portrayal of movement through the motion picture. Something over two thousand such pictures were taken by Muybridge. Many of those that had to do with the locomotion of the horse were later analyzed by Dr. J. D. B. Stillman, whose book, "The Horse in Motion," was published in 1882. Official delegates from the Academy of Motion Picture Arts and Sciences took part in the exercises. Tablets commemorating the Stanford-Muybridge research were unveiled, one in Memorial Court at



EADWEARD J. MUYBRIDGE

the main quadrangle of the university and the other, a duplicate, near the site of the Muybridge studio. Dr. Walter R. Miles, professor of experimental psychology at Stanford University, gave two addresses, "The Stanford-Muybridge Research on the Portrayal of Motion" and "Technique and Results of the Palo Alto Experiments." Among other addresses by scientific men and leaders in the motion picture industry was a talking picture address by the Honorable Ray Lyman Wilbur which was made possible through a portable outfit recently developed in the Bell Telephone Laboratories. This address for a specific occasion and presented in a college banquet hall marks an advance in motion pictures that is of much educational significance.

The motion picture art and industry has grown to immense proportions. One of its essential beginnings is associated with the Stanford University Campus in that Leland Stanford conceived and caused to be carried out a photographic investigation at his Palo Alto stock farm in 1878 and 1879. His interest in the locomotion of the horse caused him not only to take interest in the general analysis of the horse's stride, but he appreciated the individual differences and saw the importance of this in connection with his attempt to breed and rear the

MONUMENT COMMEMORATING THE STANFORD–MUYBRIDGE MOTION PICTURE RESEARCH

CONDUCTED IN 1878–1879, UNVEILED AT STANFORD UNIVERSITY, MAY 8, 1929. REPRESENTATIVES OF THE ACADEMY OF MOTION PICTURE ARTS AND SCIENCES IN ATTENDANCE AT THE DEDICATION: (LEFT TO RIGHT) WILLIAM C. DE MILLE, CLARA BERANGER (MRS. DE MILLE), ALEC B. FRANCIS, LOUIS B. MAYER, MRS. MAYER, MRS. DENNISON CLIFT, LOUIS H. TOLHURST, MRS. TOLHURST.

fastest horses. Mr. Stanford, desiring to make objective certain of the fleeting phenomena that he had learned through practice to perceive by eye, turned to photography. In general at this period, photographers were content if they could register waves of the sea and they were not striving for instantaneous pictures as we think of them to-day.

Mr. Muybridge, when lecturing about his animal photographs in the eighties, was fond of telling that at first he did not believe Leland Stanford's projection at all feasible. He considered that photographic technique was not up to the task of registering such rapid successions of motion as the running of a horse. The problem was conceived by Mr. Leland Stanford, who secured Muybridge as photographer and paid him for his services. Muybridge did the first work for Stanford in 1872 at Sacramento. Mr. Stanford moved from Sacramento to Palo Alto and established his stock farm here in 1876. Muybridge worked as a photographer in San Francisco. A man by the name of Larkyn, from Australia, fell in love with his wife; Muybridge shot Larkyn at the Yellow Jacket Mine near Calistoga, California, on October 18, 1874. He was arrested and lodged in jail and on December 8, 1874, the Grand Jury returned a bill against him. He was tried at Napa, California, beginning February 15, 1875, and the jury returned a verdict of "not guilty." Shortly after this he went to Central America and took many photographs relating to the coffee industry, returning to San Francisco sometime in 1876. Leland Stanford was then well established at Palo Alto and

wanted to continue his investigation of the locomotion of the horse. He got Mr. Muybridge to make some further trials in 1877. It was Stanford who suggested using *more than one camera*. He finally suggested using twenty-four cameras placed a foot apart, adopting this on the basis of the stride of the horse being as a rule somewhat less than twenty-four feet. He therefore conceived that the twenty-four cameras, a foot apart, would cover the longest stride and would give a sufficiently detailed analysis. A reflection screen, fifty feet long and fifteen feet high, built at an angle facing the south, provided a brilliant background against which to photograph the horse. Horizontal lines and vertical lines placed on this background provided the coordinates against which to measure the successive silhouettes. The exposures of the wet plates were of one thousandth second and shorter. John D. Isaacs, mechanical engineer, working in one of the shops connected with Mr. Stanford's railroad interests, was secured to develop better technical means of timing the photographic exposures in reference to the progress of the horse past the cameras. Isaacs devised electrical means of operating the shutters which materially advanced the research.

These were the first truly consecutive instantaneous pictures portraying rapid motion that were used by Mr. Stanford, Mr. Muybridge and others in the "wheel of life," zoetrope and other devices which had formerly been developed to give motion from series of drawings and from sets of posed photographs.

Stanford permitted Muybridge to copyright the photographs as he himself originally had no idea of publishing anything concerning the work. He kept Muybridge quite busily engaged during the years 1878 and 1879 and invested all in all about $40,000 in the project, sending Mr. Muybridge to Europe in 1881. Muybridge did not return to Palo Alto or San Francisco to take up photographic work again. He got into correspondence with Provost William Pepper in 1884. This correspondence resulted in his going to work at the University of Pennsylvania, where, according to the statement of Muybridge, "the Palo Alto outfit was duplicated" and in fact, in place of one battery of twenty-four cameras three batteries of twelve were used at different angles. In the meantime, dry plates had become available so that the photographic results were much better than the Palo Alto silhouettes.

The text of the tablets reads:

IN COMMEMORATION OF
THE MOTION PICTURE RESEARCH CONDUCTED IN 1878 AND 1879
AT THE PALO ALTO FARM NOW THE SITE OF STANFORD UNIVERSITY,
THIS EXTENSIVE PHOTOGRAPHIC EXPERIMENT PORTRAYING THE ATTITUDES OF MEN AND OF ANIMALS IN MOTION WAS CONCEIVED BY AND EXECUTED UNDER THE DIRECTION AND PATRONAGE OF
LELAND STANFORD

CONSECUTIVE INSTANTANEOUS EXPOSURES
WERE PROVIDED FOR BY A BATTERY OF TWENTY-FOUR CAMERAS FITTED WITH ELECTRO-SHUTTERS.

EADWEARD J. MUYBRIDGE, PHOTOGRAPHER,
CARRIED OUT THE INVESTIGATION AND SHOWED
THAT THE PHOTOGRAPHS COULD BE COMBINED IN PROJECTION TO GIVE THE TRUE APPEARANCE OF MOTION.

JOHN D. ISAACS, MECHANICAL ENGINEER,
ADVANCED THE RESEARCH BY DEVISING ELECTRICAL EQUIPMENT.

J. D. B. STILLMAN, M.D.,
ANALYZED THE PHOTOGRAPHS RELATING TO THE LOCOMOTION OF THE HORSE.

THIS TABLET ERECTED BY STANFORD UNIVERSITY, MAY 8, 1929.

ARTHUR S. LOEVENHART

PROFESSOR OF PHARMACOLOGY AND TOXICOLOGY IN THE UNIVERSITY OF WISCONSIN UNTIL HIS DEATH.

THE CAMPAIGN AGAINST CONSUMPTION

THE turning point in the Great War was when the allied forces fighting the Germans joined in a single coordinated plan of campaign under unified control by the appointment of General Foch, as commander-in-chief of all the armies. The turning point in a greater war may likewise date from the day when the allied forces fighting the germ of tuberculosis joined in a single coordinated plan of campaign under unified control in charge of the Research Committee of the National Tuberculosis Association. This means a revolution of the major strategy in the conquest of disease, the adoption of the policy of siege tactics and trench warfare on a large scale instead of relying upon accidental advances and the casual attacks of individual investigators as in former times. Progress under the new plan may be slow but is sure, for each foot of ground gained in advances into unknown territory is securely held. A small army of experts has volunteered service in this field, chemists, bacteriologists, druggists, physiologists and physicians, more than a hundred of them, working in various parts of the country on the common problem.

The first objective of the new campaign is the discovery of the cause of the disease. After that is attained the way will be opened for the discovery of a cure for the disease. It has long been known that tuberculosis is due to certain plant-like parasites, bacilli, or in plain English "little rods," which find a lodgment in the cells in the lungs or other parts of the body and there form nests or colonies, in the shape of little nodules, the characteristic "tubercles." But we have got to know more about these bacilli before we can fight them effectively. How does it happen that these little creatures have the power to pull down a strong young man? Why is it that a little local colony of these microscopic invaders can set up fevers and sweats in the entire frame and cause him to weaken and waste away? Do they poison him or what? Do the dead germs or the live ones do the damage? What are they made of? What do they give off while living? What do they leave when dead?

Obviously the first step in the investigation was to set the chemists to analyzing the T.B. bugs. But the chemists demanded that they be supplied with the material to be analyzed by the pound, even by the hundred pounds in the long run. So two of the leading manufacturers of medicines undertook to cultivate the creatures that they proposed to destroy. Fortunately it was found that the tuberculosis bacillus, unlike many microbes, could be made to grow outside of animals and without any animal matter. They would thrive in glass flasks filled with nutrients of known composition, made up of pure chemicals. Consequently any new substances discovered in the dead and dried germs, or in the solutions where they had lived, must be such as have been formed by the creatures themselves and such as they release inside the body. In this mass of crude material then we may expect to find the products that exert the deleterious effect upon the human system.

Although the chemical work may be said barely to have begun, yet it has already resulted in startling discoveries. Two, in especial, are altogether unexpected and without precedent. There have been found, among the toxic constituents of the T.B. germs, two that belong to two of our most familiar food families; an unknown fat that may form tubercles and an unknown sugar that may be fatal under certain circumstances. All the fats and sugars known hitherto are nutritious and innocuous. Not a disreputable member among the scores of fats and sugars found in nature or the hundreds that can be formed by the chemist.

But the newly found fat when injected into an animal will form the

same sort of tubercles as are produced by the living germs. This fat is, of course, devoid of life; in fact has been freed from all other substances in the complicated chemical process of purification. Probably when its structure has been worked out it will be found possible to make it artificially from mineral matter in the laboratory. It contains the same elements as the common fats and it seems similar in constitution to the ordinary fatty acids of foods, such for instance as stearic acid. Yet it is capable of producing all by itself the same little nodules that are characteristic of the disease and have hitherto been found only in the colonies of the living bacilli. The first effect of the injection of this fatty fraction is to stimulate the growth of the particular kind of blood cells that the T.B. bug lives in, and the abnormal multiplication of these cells upsets the balance of the body cells.

The other discovery is still more unexpected. This is a strange sugar which, when injected into the blood of a tuberculous animal, will kill it quickly. Yet it is harmless to an uninfected animal. Somehow the sugar knows. It can make a diagnosis like a doctor—or better than some. Yet the sugar is a white, harmless-looking powder, sort of sweetish like the others, made of the same elements, so it is peculiar that it should prove to have poisonous properties. It seems to act directly on the adrenal glands, causing sweats and fevers, for the secretion of the adrenals controls the temperature reactions of the body. We may surmise in advance of evidence that the familiar symptoms of the disease and its final fatal effects may be due, in part at least, to the constant leaking into the blood of this pernicious product from the T.B. germs as they die and decompose inside the cells of the afflicted individual and so slowly poison him.

This is not the only case of sugar found in disease germs, for recently some unknown sugars have been extracted from pneumonia material.

The healthy person can for a time withstand the pernicious influences emanating from the infected area, but as these increase and his resistance weakens, he fails to react as at first and the rising and falling of his temperature becomes more extreme. We may hope that eventually the chemists will find something that will break down the waste poison of the tubercle bacilli into glucose or other harmless substances.

It is already obvious that the new tactics for the investigation of disease, while at first focussed upon the tuberculosis problem, will throw light upon other diseases and in fact upon the fundamental processes of human physiology. For the three grand classes of components found in these laboratory-raised bacteria, that is, fats, sugars and proteins, are the same as constitute our bodies and our food. But how these three kinds of compounds combine in the body is still a mystery. The chemist has isolated and determined the composition and construction of all the common fats, sugars and proteins. Some of them he even can make synthetically in his laboratory. He can figure out closely just how much of these various ingredients of food are needed for a particular day's work. He can tell, for instance, just how many more foot-pounds a man can lift by adding an ounce of glucose to his ration. The chemist can trace the molecule of glucose through the blood-stream till it gets to the muscle where it is needed. But there he loses track of it. He is still much in the dark as to how the protein in the muscle fiber seizes on to the sugar and gets energy out of it and what part is played by the phosphorized fatty acids present. If he could find out how these three substances are hitched up in normal life, he would most likely be able to find out how they get hitched up wrongly in disease and finally how to correct the blunder.

EDWIN E. SLOSSON
Director of Science Service